

Vacuum probe.

Introduction¹

Potato and tapioca starch is produced from fresh raw materials with a high content of juice. The extraction of starch also releases the juice. The juice is recycled to the fields and this technical memorandum describes the effect of utilizing the juice from potatoes as a fertilizer.

The Danish starch industry processes more than half of the domestic potato crop. Production of potato starch has multiplied during the membership of the EEC, and so has the outlet of potato juice. Accordingly, the utilization of the valuable nutrients in potato juice is of great concern.

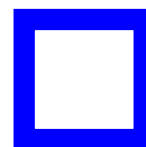
Potatoes contain approx. 70% of juice with approximately 5% of dry matter - half of which is sugars and protein bringing about 30,000 ppm BOD₅ in the concentrated juice. Being a natural product variations occur. The juice also contains potassium and magnesium and a typical analysis of fruit juice is:

Constituents of the potato juice:

| | | |
|---------------|-----------|----------------------------------|
| Nitrogen, N | 4,300 ppm | equivalent to 26,875 ppm protein |
| Phosphorus, P | 490 ppm | |
| Potassium, K | 4,900 ppm | |
| Magnesium, Mg | 260 ppm | |
| Dry substance | 5.1 % | |

These nutrients are all valuable fertilizers. Exactly how valuable and exactly what will happen when used according to good agricultural practice, were the questions to be answered by a 3- year study starting September 1988 and ending September 1991. In this study potato fruit juice was applied on grass and black uncropped soil in the autumn and spring in different quantities.

¹ The agricultural test has been planned, supervised and results interpreted by Svend Erik Simmelsgaard, The Danish Institute of Plant and Soil Science, Department of Soil Physics, Soil Tillage and Irrigation in cooperation with Lars Thomsen, International Starch Institute.



Summary and Conclusion.

The effect of manuring with potato juice on sandy soil has been studied during a three-year test period.

All three winters were mild and with a considerable nitrogen mineralization throughout the winter. The adverse effect is to some degree compensated for by the better growing conditions of grass, which has proved quite efficient in absorbing the minerals released.

| Table 11. Leaching of ammonium-nitrogen | | | | | | | | |
|---|-------------------------|------------|------------|-----------|-------------------------|-------------|------------|-----------|
| 1. September - 31. August. 1988-91. kg/ha per year. | | | | | | | | |
| KFS = Potato Juice; HG = Artificial Fertilizer Compound | | | | | | | | |
| N-applied Time: | Rye grass as catch-crop | | | | Uncropped during winter | | | |
| | KFS SEP | KFS NOV | KFS MAR | HG MAR | KFS NOV | KFS+ NOV | KFS MAR | HG MAR |
| Basic dressing | 0.13 | 0.13 | 0.13 | 0.13 | - | - | - | - |
| + 50 N | 0.13 | 0.24 | 0.13 | 0.09 | - | - | - | 0.24 |
| +100 N | 0.20 | 0.21 | 0.37 | 0.12 | 1.14 | 1.84 | 0.15 | 0.15 |
| +150 N | - | 0.28 | 0.11 | - | - | - | - | - |
| LSD (95%) | 0.20 | | | | 1.08 | | | |

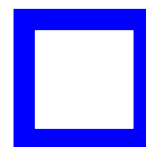
Potato juice equivalent to 100 kg nitrogen per ha applied in the autumn to black (uncropped) fields gave high losses of nitrogen during the winter due to nitrogen leaching.

Use of potato juice equivalent to 100 kg nitrogen per ha on grass as a catch crop in the autumn does not give any significant leaching of nitrogen during the winter. The utilization of nitrogen the following growing season is therefore as high as 70-80%. Potato juice equivalent to 150 kg N/ha in November increases leaching significantly and the utilization decreases correspondingly.

| Table 15. Leaching of potassium | | | | | | | | |
|---|-------------------------|------------|------------|-----------|-------------------------|-------------|------------|-----------|
| 1. September - 31. August. 1988-91. kg/ha per year. | | | | | | | | |
| N-applied Time: | Rye grass as catch-crop | | | | Uncropped during winter | | | |
| | KFS SEP | KFS NOV | KFS MAR | HG MAR | KFS NOV | KFS+ NOV | KFS MAR | HG MAR |
| Basic dressing | 35 | 35 | 35 | 35 | - | - | - | - |
| + 50 N | 37 | 34 | 31 | 32 | - | - | - | 41 |
| +100 N | 40 | 42 | 32 | 31 | 64 | 62 | 39 | 39 |
| +150 N | - | 48 | 31 | - | - | - | - | - |
| LSD (95%) | 5 | | | | 11 | | | |

Leaching of potassium does not completely match the pattern found for nitrogen.

By application in spring just prior to sowing, utilization of nitrogen in potato juice of 80-85% is expected.



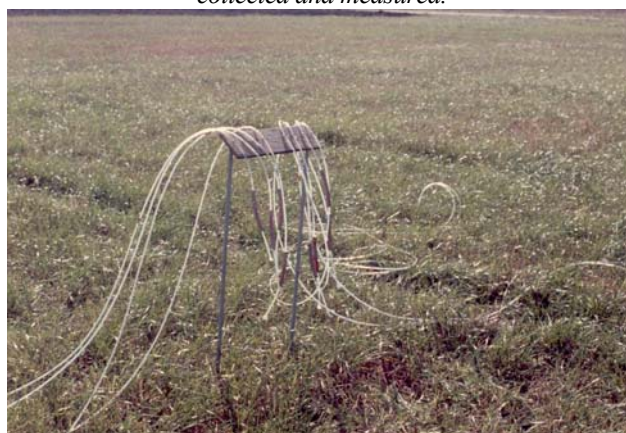
Calibration of juice spreader. The distribution of juice is checked before and after application on each plot



A mini harvester in use. The crop on individual plots are collected and measured.



Harvest of test plots. Yield of grain and straw are monitored on each plot.



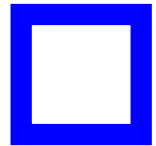
Vacuum probes with thin plastic tubes connected through the top stopper. The leaching of nutrients is monitored for each plot every week over a three-year period.

Method

The experiment was divided in 16 treatments, each with 4 repetitions as follows:

| A. GREEN | | | | B. BLACK (Catch crop: None) | | | |
|-----------------------|-------|----------|--------|-------------------------------------|-----|------------------|--------|
| Catch crop: Rye grass | | | | Round-Up used to remove vegetation. | | | |
| 1. | Basic | manuring | | 1. | 100 | N KFS, | NOV. |
| 2. | 50 | N KFS, | SEP | 2. | 100 | N KFS+inhibitor, | NOV |
| 3. | 100 | N KFS, | SEP | 3. | 50 | N HG, | spring |
| 4. | 50 | N KFS, | NOV | 4. | 100 | N HG, | spring |
| 5. | 100 | N KFS, | NOV | 5. | 100 | N KFS, | spring |
| 6. | 150 | N KFS, | NOV | | | | |
| 7. | 50 | N HG, | spring | | | | |
| 8. | 100 | N HG, | spring | | | | |
| 9. | 50 | N KFS, | spring | | | | |
| 10. | 100 | N KFS, | spring | | | | |
| 11. | 150 | N KFS, | spring | | | | |

Basic = Basic dressing with P, K + N (30 kg/ha N) H in spring
 HG = Artificial fertilizer
 N = Total nitrogen, kg/ha
 KFS = Potato juice undiluted
 Inhibitor= Nitrification inhibitor



The experiment took place on sandy soil in Jutland, Denmark. All 64 plots had spring barley in all three years. The straw is removed after harvest and the outgrown plots are harvested in the autumn. 20 plots planned without vegetation through out the winter are then sprayed down with Round-Up. In spring all plots are ploughed. In summer time the plots are irrigated when needed.

For each plot the yields of dry matter, nitrogen and potassium content in grain, straw and stubble are measured. Dry matter and nitrogen content of grass is determined by sampling after harvest, in November and again before ploughing in spring.

The leaching of nitrogen and potassium is calculated on the basis of analysis of soil water taken out at a depth of 80 cm, combined with model calculations of the percolation in the same depth.

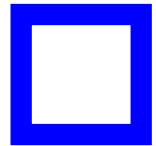
The soil water is sampled by vacuum. A hole is drilled down below the root zone. A vacuum probe (picture frontpage) is forced down the hole to the bottom and sealed carefully with volcanic clay. In most cases the seal was efficient to keep vacuum for more than a week. The vacuum probe is a plastic pipe with a ceramic cup (filter) at the lower end and a rubber stopper at the top. The stopper is provided with two holes for two thin sampling tubes - a short one to the top of the probe and a longer one to the bottom of the probe. With a portable vacuum pump connected to the short tube the probe is put under vacuum and the tube is closed. The vacuum slowly draws soil water into the probe. During sampling air pressure is applied to the short tube forcing trapped water up and out through the long tube into a bottle. Because the ceramic filter is below the root zone the sampled water represents a potential leaching hazard. Each test plot is provided with two sampling tubes. That means a total of 8 samplings per treatment and a total of 128 samples each day of sampling. The two samples from each plot are mixed to a joint sample for that plot. On average, sampling is done every second week. Each soil water sample is analyzed for nitrate. Potassium and ammonium is analyzed monthly.

The soil water analysis is supplemented with analysis of soil samples taken 0-25, 25-50 and 50-75 cm below soil surface before the outbringing of juice in September, November and March. 4 - 5 samples are taken from each plot and mixed, which means 17 - 20 samples per treatment. Before starting the trial, soil samples have been analyzed for pH, potassium (K), phosphor (P) and total nitrogen (N), total organic carbon C and texture. In the experiment period each soil sample is analyzed for nitrate + ammonium (N_{\min}) and potassium. At the end of the test total nitrogen and total organic carbon have been measured.

Before the start of the test four soil profiles have been described. In each profile 18 cores of undisturbed soil (volume = 100 cm^3) - five from a depth of 10 and 37 cm, four samples from a depth of 52 and 77 cm - were sampled for retention analysis. From the retention analysis the root zone capacity for plant available water were calculated.

The calculations of actual evaporation/transpiration and percolation are performed on the basis of climate data obtained from a nearby weather station. Only rainfall is measured directly on the test area. For the calculations the Evacrop² water balance model is used. The leaching is calculated by multiplying the percolation with the average concentration between two sampling dates.

² Reference: *AjMet nr. 9, Department of Agricultural Meteorology, Institute of Plant and Soil Science*
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The soil is coarse sandy and classified as JB no 1 in the Danish classification system. The analysis of texture is shown in table 1. There is a tendency towards forming of hard pan in part of the area, which has been grubbed (broken) earlier. The underground is somewhere graveled.

Climate

The average temperature and rainfall are shown in figure 2.

Table 5 gives the water balance for the 3 years of test calculated from 1st of September to the 31st of August and figure 5 shows the calculated amounts of percolation.

In figure 1 the retention curve is shown. The retention curves show the relation between the logarithms and the suction in cm (pF) and the water content of the soil gives thereby an impression of the ability to retain water.

In table 2 dry volume weight, porosity and the water capacity calculated from the retention curves are shown. The volume weight and the porosity are normal for the soil type.

With an estimated efficient depth of the plant roots of 60 cm the root zone capacity for plant available water is 72 cm. In the area with hard pan the efficient depth of the plant roots is estimated to be less than 60 cm. There is a compensation - the soil in this area will be expected to retain a little more water at field capacity, which will compensate for a minor depth of the roots.

In table 3 the results of chemical analysis of soil samples taken at the start of the September 1988 are shown. pH and phosphor content P is normal, while potassium K and magnesium Mg are low. The carbon content of the soil in relation to organic bound nitrogen, C/N, is rather high, which means that a tendency towards immobilization of nitrogen is to be expected.

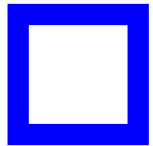
The outbringing of potato juice (PJ).

A Hardi field sprayer is used for the outbringing of the potato juice. The pump yields 150 to 160 litres per minute with a pressure of 2.5 bar. On a 5 m long spraying boom 19 nozzles are mounted. Before and after each application of potato juice the yield of the spray equipment was monitored.

The speed of the tractor was adjusted so each passing of a plot gave exactly 50 kg of nitrogen per ha. The speed was stopwatch-monitored and the amount of potato juice was also monitored by collecting fruit juice in four trays placed on each plot during passing. The figures obtained are shown in table 4. The stopwatch method is well in agreement with the method of collecting juice in trays, except for one treatment in November 1989 where heavy wind drift may have compromised the sampling. The outbringing has been based on estimated values for nitrogen content, which in 1989 gave some disagreement between the two methods.

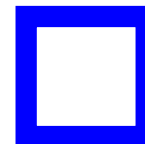
Plots not fertilized with fruit juice and plots fertilized with only 50 and 100 kg of nitrogen per ha as fruit juice had received supplementary potassium and phosphor as PK-fertilizer. Nitrogen was given in the form of calcium-ammonium-nitrate (KAS).

The actual quantities of nitrogen and potassium per plot are given in table A5 to A12.



Abbreviations

| | |
|--|--|
| KFS | Potato juice undiluted |
| KFS+ | Potato juice with nitrification inhibitor (Didin) added |
| HG | Artificial fertilizer |
| KAS | Calcium Ammonium Nitrate (Kalkammonsalpeter) |
| N | Nitrogen |
| K | Potassium |
| P | Phosphorous |
| C | Carbon |
| LSD | Least significant difference |
| SEP | September |
| NOV | November |
| MAR | Marts |
| $N\text{-balance} = N_{\text{til}} - N_{\text{opt}} + N_{\text{min}}(\text{start}) - N_{\text{min}}(\text{end})$ | |
| N_{til} | Nitrogen added as KFS or HG. Nitrogen from other sources (app. 20 N kg/ha) rainfall, irrigation etc. is not included in balance calculations |
| N_{opt} | Nitrogen retained in grain and stubble |
| N_{udv} | Nitrogen washed out |
| N_{min} | Nitrogen inorganic (mineralized) |
| UDL | Barley with undersown rye grass |



| Depth cm | Humus Org. matter | Clay <0.002 | Silt <0.02 | Fine sand <0.2 | Coarse sand <2 mm | Gravel/ stone >2 mm |
|-------------|-------------------------|----------------|---------------|----------------------|-------------------------|---------------------------|
| 0-25 | 3.2 | 3.9 | 3.1 | 23.2 | 62.7 | 4.0 |
| 25-50 | 1.4 | 3.2 | 1.7 | 22.2 | 64.8 | 6.8 |
| 50-75 | 0.5 | 2.6 | 0.9 | 20.3 | 68.5 | 7.3 |

| Depth cm | Volume- weight g/cm ³ | Porosity % | Field capacity pF = 2.0 mm | Plant in- available water pF = 4.2 mm | Plant available water mm |
|-------------|--|---------------|-------------------------------------|---|-----------------------------------|
| 0-25 | 1.47 | 43.4 | 48.2 | 11.0 | 37.2 |
| 25-45 | 1.53 | 41.9 | 26.2 | 5.3 | 20.9 |
| 45-60 | 1.48 | 43.9 | 16.2 | 2.6 | 13.6 |
| 60-100 | 1.56 | 41.1 | 47.6 | 4.4 | 43.2 |
| 0-60 | - | - | 91 | 19 | 72* |
| 0-100 | - | - | 138 | 23 | 115 |

* Root zone capacity

| Depth cm | pH water | P | K | Mg | Total- C % | Total N % | C/N |
|-------------|-------------|--------------|-----|-----|------------------|-----------------|------|
| | | mg/100g soil | | | | | |
| 0-25 | 6.5 | 4.3 | 4.3 | 1.7 | 1.90 | 0.092 | 20.7 |
| 25-50 | 5.9 | 1.1 | 2.4 | 0.7 | 0.89 | 0.035 | 25.5 |
| 50-75 | 5.9 | 0.2 | 1.4 | 0.3 | 0.31 | 0.013 | 24.8 |
| | | kg/ha | | | ton/ha | | |
| 0-25 | - | 158 | 158 | 62 | 69.8 | 3.38 | - |
| 25-50 | - | 42 | 92 | 27 | 34.0 | 1.34 | - |
| 50-75 | - | 8 | 53 | 11 | 11.8 | 0.49 | - |
| 0- 75 | - | 208 | 303 | 100 | 115.6 | 5.21 | 22.2 |

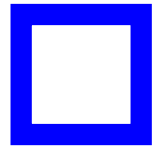


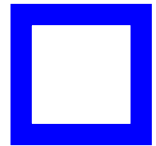
Table 4. Quantity of potato juice applied in one-pass

| Date | Measured | | N- content kg/ton | N- applied kg/ha | K- content kg/ton | K- applied kg/ha |
|------------|--------------------|---------------------|-------------------------|------------------------|-------------------------|------------------------|
| | in trays ton/ha | stopwatch ton/ha | | | | |
| 20.09.1988 | 13.1 | 13.1 | 3.9 | 51 | 5.1 | 67 |
| 16.11.1988 | 13.5 | 13.4 | 3.6 | 48 | 4.6 | 62 |
| 14.03.1989 | 14.5 | 14.2 | 3.4 | 48 | 3.9 | 55 |
| 13.09.1989 | 13.7 | 13.9 | 5.3 | 73 | 5.4 | 75 |
| 15.11.1989 | 11.8 | 14.0 | 4.7 | 66 | 4.9 | 69 |
| 21.03.1990 | 14.8 | 14.7 | 3.4 | 50 | 4.4 | 65 |
| 24.09.1990 | 14.5 | 13.7 | 3.7 | 51 | 3.6 | 49 |
| 15.11.1990 | 12.1 | 11.7 | 4.3 | 50 | 5.0 | 59 |
| 20.03.1991 | 11.0 | 11.8 | 3.8 | 44 | 4.3 | 50 |

Table 5. Rainfall, irrigation, evaporation and run off
1. SEP - 31. Aug., 1988-91, mm per year.

| Year | Rainfall | Irrigation | Evaporation | | Run off | |
|---------|----------|------------|-------------|-----|---------|-----|
| | Precipi. | | Barley | UDL | Barley | UDL |
| 1988/89 | 797 | 68 | 449 | 466 | 455 | 451 |
| 1989/90 | 851 | 76 | 455 | 497 | 451 | 420 |
| 1990/91 | 882 | 17 | 388 | 409 | 541 | 506 |

UDL = Barley with undersown grass.



| Table 6. Grain yield of spring barley (85% DS), hkg/ha. | | | | | | | | |
|--|-----------------------|------------|------------|-----------|-------------------------|-------------|------------|-----------|
| N-applied | Rye grass catch-crop. | | | | Uncropped during winter | | | |
| | KFS SEP | KFS NOV | KFS MAR | HG MAR | KFS NOV | KFS+ NOV | KFS MAR | HG MAR |
| Time: | | | | | | | | |
| <i>1989:</i> | | | | | | | | |
| Basic dressing | 27.0 | 27.0 | 27.0 | 27.0 | - | - | - | - |
| + 50 N | 35.7 | 38.0 | 33.6 | 33.0 | - | - | - | 30.4 |
| +100 N | 43.3 | 44.7 | 41.6 | 41.6 | 24.0 | 25.2 | 38.4 | 37.5 |
| +150 N | - | 47.3 | 45.8 | - | - | - | - | - |
| LSD (95%) | 3.8 | | | | 2.4 | | | |
| <i>1990:</i> | | | | | | | | |
| Basic dressing | 34.7 | 34.7 | 34.7 | 34.7 | - | - | - | - |
| + 50 N | 40.5* | 43.8* | 43.9 | 48.2 | - | - | - | 47.5 |
| +100 N | 46.9* | 49.3* | 53.7 | 58.6 | 33.1 | 34.7 | 51.0 | 55.2 |
| +150 N | - | 51.0* | 61.2 | - | - | - | - | - |
| LSD (95%) | 2.7 | | | | 2.2 | | | |
| <i>1991:</i> | | | | | | | | |
| Basic dressing | 23.8 | 23.8 | 23.8 | 23.8 | - | - | - | - |
| + 50 N | 30.6 | 30.8 | 29.5 | 32.7 | - | - | - | 22.0 |
| +100 N | 33.9 | 34.4 | 34.8 | 38.9 | 15.1 | 16.4 | 23.9 | 25.9 |
| +150 N | - | 35.1 | 39.4 | - | - | - | - | - |
| LSD (95%) | 2.7 | | | | 2.3 | | | |
| <i>Average 1989-91:</i> | | | | | | | | |
| Basic dressing | 28.5 | 28.5 | 28.5 | 28.5 | - | - | - | - |
| + 50 N | 36.5 | 38.5 | 35.6 | 37.9 | - | - | - | 33.3 |
| +100 N | 43.2 | 43.1 | 43.4 | 46.3 | 24.1 | 25.4 | 37.7 | 39.5 |
| +150 N | - | 44.5 | 48.8 | - | - | - | - | - |
| LSD (95%) | 2.6 | | | | 1.1 | | | |

*Corrected to yield by nominal N-applied

KFS = Potato juice, KFS+ = Potato juice + nitrification inhibitor,
HG = Artificial fertilizer.

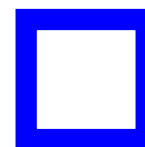


Table 7. Content of nitrogen in rye grass (top + stubble), kg/ha

| Treatment | 1988/89 | 1989/90 | | | 1990/91 | | |
|---------------------|---------|----------|-----|-----|----------|-----|-----|
| | MAR | Har-vest | NOV | MAR | Har-vest | NOV | MAR |
| 1. Basic dressing | 44 | 6 | 23 | 19 | 5 | 16 | 22 |
| 2. 50 N i KFS, SEP | 67 | - | 57 | 45 | 5 | 28 | 41 |
| 3. 100 N i KFS, SEP | 103 | - | 91 | 66 | 5 | 36 | 60 |
| 4. 50 N i KFS, NOV | 63 | - | 26 | 34 | 5 | 22 | 40 |
| 5. 100 N i KFS NOV | 76 | - | 23 | 33 | 4 | 19 | 46 |
| 6. 150 N i KFS NOV | 91 | - | 27 | 34 | 4 | 22 | 45 |
| 8. 100 N i HG, MAR | - | - | - | 22 | - | 16 | 27 |
| 9. 50 N i KFS, MAR | - | 6 | - | - | - | - | - |
| 10 100 N i KFS, MAR | - | 6 | - | 21 | 7 | 23 | 28 |
| 11 150 N i KFS, MAR | - | 7 | 36 | - | - | - | - |

Table 8. Nitrogen content in grain + straw.
Average 1989-91, kg/ha.

| N-applied | Rye grass catch-crop | | | | Uncropped during winter | | | |
|----------------|----------------------|------|-------|------|-------------------------|------|-------|------|
| | KFS | KFS | KFS | HG | KFS | KFS+ | KFS | HG |
| Time: | SEP | NOV | MAR | MAR | SEP | NOV | MAR | MAR |
| Basic dressing | 38.7 | 38.7 | 38.7 | 38.7 | - | - | - | - |
| + 50 N | 52.8 | 55.4 | 51.3 | 54.0 | - | - | - | 49.2 |
| +100 N | 68.2 | 64.9 | 69.8 | 73.4 | 36.1 | 37.9 | 60.7 | 65.3 |
| +150 N | - | 71.4 | 89.4 | - | - | - | - | - |
| LSD (95%) | ***** | 3.9 | ***** | | ***** | 2.0 | ***** | |

Table 9. Potassium content in grain + straw.
Average 1989-91, kg/ha.

| N-applied | Rye grass catch-crop | | | | Uncropped during winter | | | |
|----------------|----------------------|------|-------|------|-------------------------|------|-------|------|
| | KFS | KFS | KFS | HG | KFS | KFS+ | KFS | HG |
| Time: | SEP | NOV | MAR | MAR | SEP | NOV | MAR | MAR |
| Basic dressing | 28.0 | 28.0 | 28.0 | 28.0 | - | - | - | - |
| + 50 N | 38.4 | 40.7 | 45.5 | 39.9 | - | - | - | 40.5 |
| +100 N | 49.3 | 46.7 | 50.9 | 52.3 | 30.1 | 31.3 | 51.2 | 49.4 |
| +150 N | - | 48.5 | 64.1 | - | - | - | - | - |
| LSD (95%) | ***** | 5.8 | ***** | | ***** | 2.8 | ***** | |

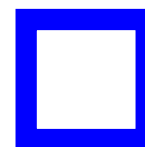


Table 10. Leaching of nitrate nitrogen

1. September - 31. August. kg/ha.

| N-applied | Rye grass catch-crop | | | | Uncropped fields | | | |
|----------------------|----------------------|-------|-------|-------|------------------|------|-------|-------|
| | KFS | KFS | KFS | HG | KFS | KFS+ | KFS | HG |
| Time: | SEP | NOV | MAR | MAR | NOV | NOV | MAR | MAR |
| <i>1989:</i> | | | | | | | | |
| Basic dressing | 5,7 | 5.7 | 5.7 | 5.7 | - | - | - | - |
| + 50 N | 6.7 | 7.5 | 4.5 | 4.7 | - | - | - | 30.9 |
| +100 N | 6.0 | 8.8 | 4.1 | 4.4 | 98.6 | 57.0 | 30.8 | 30.9 |
| +150 N | - | 17.5 | 6.0 | - | - | - | - | - |
| LSD (95%) | ***** | 5.4 | ***** | ***** | ***** | 16.7 | ***** | ***** |
| <i>1990:</i> | | | | | | | | |
| Basic dressing | 1.7 | 1.7 | 1.7 | 1.7 | - | - | - | - |
| + 50 N | 2.2* | 1.5* | 1.5 | 1.5 | - | - | - | 29.9 |
| +100 N | 5.1* | 9.2* | 3.4 | 2.9 | 84.5 | 63.6 | 40.1 | 36.4 |
| +150 N | - | 25.3* | 1.7 | - | - | - | - | - |
| LSD (95%) | ***** | 8.7 | ***** | ***** | ***** | 11.4 | ***** | ***** |
| <i>1991:</i> | | | | | | | | |
| Basic dressing | 4.8 | 4.8 | 4.8 | 4.8 | - | - | - | - |
| + 50 N | 7.4 | 15.3 | 5.0 | 7.4 | - | - | - | 59.9 |
| +100 N | 15.9 | 12.6 | 8.3 | 10.7 | 90.4 | 91.4 | 68.0 | 57.6 |
| +150 N | - | 33.9 | 9.9 | - | - | - | - | - |
| LSD (95%) | ***** | 9.6 | ***** | ***** | ***** | 10.3 | ***** | ***** |
| <i>Ave. 1989-91:</i> | | | | | | | | |
| Basic dressing | 4.1 | 4.1 | 4.1 | 4.1 | - | - | - | - |
| + 50 N | 5.4 | 8.1 | 3.7 | 4.5 | - | - | - | 40.2 |
| +100 N | 9.0 | 10.2 | 5.3 | 6.0 | 91.2 | 70.7 | 46.3 | 41.6 |
| +150 N | - | 25.6 | 5.9 | - | - | - | - | - |
| LSD (95%) | ***** | 5.1 | ***** | ***** | ***** | 7.5 | ***** | ***** |

*Corrected to yield at nominal N-applied

KFS+ = Potato juice with nitrification inhibitor added.

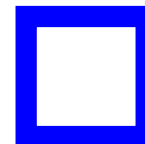


Table 11. Leaching of ammonium-nitrogen
1. September - 31. August. 1988-91. kg/ha per year.

| N-applied Time: | Rye grass catch-crop | | | | Uncropped during winter | | | |
|--------------------|----------------------|------------|------------|-----------|-------------------------|-------------|------------|-----------|
| | KFS SEP | KFS NOV | KFS MAR | HG MAR | KFS NOV | KFS+ NOV | KFS MAR | HG MAR |
| Basic dressing | 0.13 | 0.13 | 0.13 | 0.13 | - | - | - | - |
| + 50 N | 0.13 | 0.24 | 0.13 | 0.09 | - | - | - | 0.24 |
| +100 N | 0.20 | 0.21 | 0.37 | 0.12 | 1.14 | 1.84 | 0.15 | 0.15 |
| +150 N | - | 0.28 | 0.11 | - | - | - | - | - |
| LSD (95%) | 0.20 | | | | 1.08 | | | |

Table 12. Mean concentration of ammonium-nitrogen
weighted in relation to the run off. 1988-91, mg/l.

| N-applied Time: | Rye grass catch-crop | | | | Uncropped during winter | | | |
|--------------------|----------------------|------------|------------|-----------|-------------------------|-------------|------------|-----------|
| | KFS SEP | KFS NOV | KFS MAR | HG MAR | KFS NOV | KFS+ NOV | KFS MAR | HG MAR |
| Basic dressing | 0.03 | 0.03 | 0.03 | 0.03 | - | - | - | - |
| + 50 N | 0.03 | 0.05 | 0.03 | 0.02 | - | - | - | 0.05 |
| +100 N | 0.04 | 0.05 | 0.08 | 0.03 | 0.25 | 0.39 | 0.03 | 0.03 |
| +150 N | - | 0.06 | 0.02 | - | - | - | - | - |

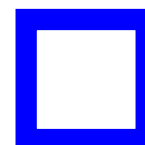


Table 13. Accumulated nitrogen balance, SEP 88 - SEP 91, kg/ha

| N-applied | Rye grass catch-crop | | | | Uncropped fields | | | |
|----------------|----------------------|-----|-----|-----|------------------|------|-----|-----|
| | KFS | KFS | KFS | HG | KFS | KFS+ | KFS | HG |
| Time | SEP | NOV | MAR | MAR | NOV | NOV | MAR | MAR |
| Basic dressing | -53 | -53 | -53 | -53 | - | - | - | - |
| +50 N | 70 | 36 | 49 | 49 | - | - | - | -49 |
| +100 N | 174 | 155 | 125 | 122 | 30 | 97 | 25 | 41 |
| +150 N | - | 234 | 194 | - | - | - | - | - |

Table 14. Soil content of total-N at 0 - 25 cm depth
At the end of the trial, SEP 1991, ton/ha.

| N-applied | Rye grass catch-crop | | | | Uncropped fields | | | |
|----------------|----------------------|-----|-------|-----|------------------|------|-------|-----|
| | KFS | KFS | KFS | HG | KFS | KFS+ | KFS | HG |
| Time | SEP | NOV | MAR | MAR | NOV | NOV | MAR | MAR |
| Basic dressing | 3.3 | 3.3 | 3.3 | 3.3 | - | - | - | - |
| +50 N | 3.5 | 3.4 | 3.6 | 3.7 | - | - | - | 3.6 |
| +100 N | 3.8 | 3.5 | 3.6 | 3.7 | 3.2 | 3.3 | 3.5 | 3.3 |
| +150 N | - | 3.6 | 3.5 | - | - | - | - | - |
| LSD (95%) | ***** | 0.4 | ***** | | ***** | n.s. | ***** | |

Table 15. Leaching of potassium

1. September - 31. August. 1988-91. kg/ha per year.

| N-applied Time: | Rye grass catch-crop | | | | Uncropped during winter | | | |
|--------------------|----------------------|-----|-----|-----|-------------------------|------|-----|-----|
| | KFS | KFS | KFS | HG | KFS | KFS+ | KFS | HG |
| | SEP | NOV | MAR | MAR | NOV | NOV | MAR | MAR |
| Basic dressing | 35 | 35 | 35 | 35 | - | - | - | - |
| + 50 N | 37 | 34 | 31 | 32 | - | - | - | 41 |
| +100 N | 40 | 42 | 32 | 31 | 64 | 62 | 39 | 39 |
| +150 N | - | 48 | 31 | - | - | - | - | - |
| LSD (95%) | 5 | | | | 11 | | | |

Table 16. Mean concentration of potassium,
weighted in relation to run off, 1988-91, mg/l.

| N-applied | Rye grass catch-crop | | | | Uncropped during winter | | | |
|----------------|----------------------|------|-----|-----|-------------------------|------|-----|-----|
| | KFS | KFS | KFS | HG | KFS | KFS+ | KFS | HG |
| Time: | SEP | NOV | MAR | MAR | NOV | NOV | MAR | MAR |
| Basic dressing | 7.9 | 7.9 | 7.9 | 7.9 | - | - | - | - |
| + 50 N | 8.5 | 7.6 | 7.0 | 7.2 | - | - | - | 9.0 |
| +100 N | 8.9 | 9.6 | 7.4 | 7.1 | 13.7 | 13.2 | 8.6 | 8.6 |
| +150 N | - | 10.8 | 7.0 | - | - | - | - | - |

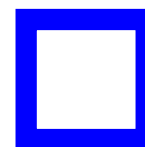


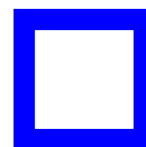
Table A1. Grain- and straw yield (85% DS.), hkg/ha.

| Treatment | Grain | | | | Straw | | | |
|-----------------------------------|-------|------|------|------|-------|------|------|------|
| | 1989 | 1990 | 1991 | Ave. | 1989 | 1990 | 1991 | Ave. |
| A: Catch-crop of rye grass | | | | | | | | |
| 1: Basic dress | 27.0 | 34.7 | 23.8 | 28.5 | 12.3 | 17.6 | 10.7 | 13.5 |
| 2: 50 N SEP | 35.7 | 43.1 | 30.6 | 36.5 | 16.5 | 25.7 | 16.4 | 19.5 |
| 3: 100 N SEP | 43.3 | 52.5 | 33.9 | 43.2 | 21.4 | 33.9 | 19.1 | 24.8 |
| 4: 50 N NOV | 38.0 | 46.7 | 30.8 | 38.5 | 17.8 | 28.7 | 14.9 | 20.4 |
| 5: 100 N NOV | 44.7 | 50.3 | 34.4 | 43.1 | 21.8 | 32.1 | 19.0 | 24.3 |
| 6: 150 N NOV | 47.3 | 51.0 | 35.1 | 44.5 | 24.2 | 32.3 | 20.2 | 25.6 |
| 7: 50 N KAS | 33.0 | 48.2 | 32.7 | 37.9 | 16.5 | 29.5 | 14.6 | 20.2 |
| 8: 100 N KAS | 41.6 | 58.6 | 38.9 | 46.3 | 20.4 | 37.1 | 21.2 | 26.2 |
| 9: 50 N MAR | 33.6 | 43.9 | 29.5 | 35.6 | 16.4 | 26.6 | 14.9 | 19.3 |
| 10 100 N MAR | 41.6 | 53.7 | 34.8 | 43.4 | 21.5 | 34.5 | 18.3 | 24.8 |
| 11 150 N MAR | 45.8 | 61.2 | 39.4 | 48.8 | 24.8 | 41.0 | 25.7 | 30.5 |
| LSD (95%) | 3.8 | 2.7 | 2.7 | 2.6 | 2.9 | 3.5 | 2.7 | 2.5 |
| B: Uncropped during winter | | | | | | | | |
| 1: 100 N NOV | 24.0 | 33.1 | 15.1 | 24.1 | 12.8 | 21.2 | 9.9 | 14.6 |
| 2: 100 N NOV+ | 25.2 | 34.7 | 16.4 | 25.4 | 11.7 | 19.9 | 9.9 | 14.0 |
| 3: 50 N KAS | 30.4 | 47.5 | 22.0 | 33.3 | 15.5 | 30.0 | 14.7 | 20.1 |
| 4: 100 N KAS | 37.5 | 55.2 | 25.9 | 39.5 | 20.2 | 36.7 | 16.8 | 24.6 |
| 5: 100 N MAR | 38.4 | 51.0 | 23.9 | 37.7 | 19.9 | 34.0 | 18.9 | 24.3 |
| LSD (95%) | 2.4 | 2.2 | 2.3 | 1.1 | 1.5 | 2.5 | 2.9 | 1.6 |

KAS = calcium ammonium nitrate

Table A2. Nitrogen content in grain and straw, kg/ha.

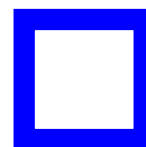
| Treatment | Grain | | | | Straw | | | |
|-----------------------------------|-------|------|------|------|-------|------|------|------|
| | 1989 | 1990 | 1991 | Ave. | 1989 | 1990 | 1991 | Ave. |
| A: Catch-crop of rye grass | | | | | | | | |
| 1: Basic dress | 30.4 | 40.4 | 28.0 | 32.9 | 4.9 | 7.6 | 4.8 | 5.8 |
| 2: 50 N SEP | 40.7 | 52.9 | 39.5 | 44.4 | 6.6 | 11.4 | 7.2 | 8.4 |
| 3: 100 N SEP | 52.0 | 70.1 | 47.7 | 56.6 | 8.7 | 17.0 | 9.0 | 11.6 |
| 4: 50 N NOV | 43.4 | 58.1 | 38.9 | 46.8 | 6.9 | 12.1 | 6.9 | 8.6 |
| 5: 100 N NOV | 54.0 | 62.6 | 46.4 | 54.3 | 9.5 | 13.8 | 8.4 | 10.6 |
| 6: 150 N NOV | 61.8 | 66.2 | 50.2 | 59.4 | 12.1 | 14.6 | 9.4 | 12.0 |
| 7: 50 N KAS | 37.1 | 57.7 | 41.1 | 45.3 | 6.6 | 13.2 | 6.2 | 8.7 |
| 8: 100 N KAS | 48.6 | 78.9 | 55.4 | 61.0 | 9.3 | 17.9 | 10.1 | 12.4 |
| 9: 50 N MAR | 37.9 | 53.0 | 37.3 | 42.7 | 6.7 | 12.2 | 6.8 | 8.6 |
| 10 100 N MAR | 50.1 | 72.1 | 48.6 | 57.0 | 11.2 | 17.9 | 9.3 | 12.8 |
| 11 150 N MAR | 61.4 | 92.1 | 62.5 | 72.0 | 14.3 | 23.7 | 14.1 | 17.4 |
| LSD (95%) | 4.0 | 3.9 | 3.8 | 3.2 | 1.4 | 2.2 | 1.5 | 1.2 |
| B: Uncropped during winter | | | | | | | | |
| 1: 100 N NOV | 29.0 | 39.5 | 18.4 | 29.0 | 5.5 | 9.5 | 6.5 | 7.2 |
| 2: 100 N NOV+ | 30.4 | 41.3 | 20.8 | 30.9 | 5.5 | 8.7 | 6.6 | 7.0 |
| 3: 50 N KAS | 35.5 | 56.4 | 27.8 | 39.9 | 5.9 | 12.9 | 9.1 | 9.3 |
| 4: 100 N KAS | 45.9 | 76.6 | 37.4 | 53.3 | 8.0 | 17.5 | 10.3 | 12.0 |
| 5: 100 N MAR | 46.8 | 66.2 | 32.6 | 48.5 | 7.9 | 16.3 | 12.3 | 12.2 |
| LSD (95%) | 3.4 | 3.9 | 3.2 | 1.7 | 1.0 | 1.4 | 2.3 | 0.9 |


Table A3. Potassium content in grain and straw, kg/ha.

| Treatment | Grain | | | | Straw | | | |
|-----------------------------------|-------|------|------|------|-------|------|------|------|
| | 1989 | 1990 | 1991 | Ave. | 1989 | 1990 | 1991 | Ave. |
| A: Catch-crop of rye grass | | | | | | | | |
| 1: Basic dress | 10.1 | 17.3 | 10.6 | 12.7 | 8.0 | 29.5 | 8.4 | 15.3 |
| 2: 50 N SEP | 13.2 | 21.4 | 13.1 | 15.9 | 10.6 | 45.2 | 11.6 | 22.5 |
| 3: 100 N SEP | 15.7 | 25.8 | 13.9 | 18.4 | 14.4 | 62.4 | 15.7 | 30.8 |
| 4: 50 N NOV | 13.9 | 22.9 | 13.2 | 16.7 | 11.2 | 48.7 | 12.1 | 24.0 |
| 5: 100 N NOV | 16.4 | 25.3 | 14.3 | 18.7 | 15.5 | 53.8 | 14.9 | 28.0 |
| 6: 150 N NOV | 17.6 | 25.1 | 15.6 | 19.4 | 18.9 | 50.3 | 18.1 | 29.1 |
| 7: 50 N KAS | 12.1 | 22.9 | 14.1 | 16.4 | 9.5 | 51.1 | 10.0 | 23.5 |
| 8: 100 N KAS | 14.3 | 28.6 | 16.2 | 19.7 | 11.7 | 72.2 | 14.0 | 32.6 |
| 9: 50 N MAR | 12.3 | 21.6 | 13.2 | 15.7 | 9.8 | 46.7 | 32.8 | 29.8 |
| 10: 100 N MAR | 15.0 | 26.5 | 15.1 | 18.9 | 15.8 | 65.3 | 15.0 | 32.1 |
| 11: 150 N MAR | 16.7 | 29.9 | 17.3 | 21.3 | 20.4 | 84.3 | 23.6 | 42.8 |
| LSD (95%) | 1.5 | 1.9 | 2.1 | 1.4 | 2.7 | 7.2 | 18.7 | 5.9 |
| B: Uncropped during winter | | | | | | | | |
| 1: 100 N NOV | 9.4 | 16.3 | 6.8 | 10.8 | 9.6 | 33.3 | 15.1 | 19.3 |
| 2: 100 N NOV+ | 9.6 | 16.8 | 7.4 | 11.3 | 9.0 | 32.6 | 14.2 | 19.5 |
| 3: 50 N KAS | 11.0 | 22.4 | 9.6 | 14.3 | 9.7 | 48.2 | 20.5 | 26.1 |
| 4: 100 N KAS | 13.2 | 26.5 | 11.2 | 17.0 | 12.4 | 66.2 | 18.6 | 32.4 |
| 5: 100 N MAR | 13.9 | 24.8 | 11.0 | 16.6 | 13.9 | 60.3 | 29.7 | 34.6 |
| LSD (95%) | 0.8 | 1.1 | 1.1 | 0.5 | 1.8 | 4.0 | 6.1 | 2.4 |

Table A4. Stubble Yield and N-content in stubble. hkg/ha & kg/ha.

| Treatment | Yield | | | | N-content | | | |
|-----------------------------------|-------|------|------|------|-----------|------|------|------|
| | 1989 | 1990 | 1991 | Ave. | 1989 | 1990 | 1991 | Ave. |
| A: Catch-crop of rye grass | | | | | | | | |
| 1: Basic dress. | 4.6 | 10.0 | 6.0 | 6.9 | 2.1 | 7.3 | 3.6 | 4.4 |
| 2: 50 N SEP | . | 10.0 | 5.9 | 7.9 | . | 7.7 | 3.8 | 5.7 |
| 3: 100 N SEP | 6.2 | 11.0 | 6.1 | 7.8 | 3.2 | 8.5 | 4.0 | 5.2 |
| 4: 50 N NOV | 5.7 | 12.7 | 5.7 | 8.0 | 2.8 | 9.4 | 3.7 | 5.3 |
| 5: 100 N NOV | 5.9 | 12.7 | 6.4 | 8.3 | 2.9 | 10.2 | 4.1 | 5.7 |
| 6: 150 N NOV | 7.1 | 12.5 | 6.2 | 8.6 | 4.1 | 10.2 | 4.2 | 6.2 |
| 7: 50 N KAS | 5.5 | 12.6 | 6.9 | 8.4 | 2.6 | 10.3 | 4.5 | 5.8 |
| 8: 100 N KAS | 7.2 | 13.2 | 7.7 | 9.4 | 3.8 | 11.2 | 5.8 | 6.9 |
| 9: 50 N MAR | 5.6 | 11.0 | 5.6 | 7.4 | 2.5 | 9.2 | 3.6 | 5.1 |
| 10: 100 N MAR | 5.2 | 14.7 | 4.9 | 8.3 | 2.7 | 12.3 | 3.4 | 6.1 |
| 11: 150 N MAR | 7.5 | 11.3 | 6.5 | 8.4 | 4.8 | 11.3 | 5.0 | 7.0 |
| LSD (95%) | - | - | 1.8 | 1.2 | - | - | 1.2 | 1.1 |
| B: Uncropped during winter | | | | | | | | |
| 1: 100 N NOV | 5.0 | 9.7 | 4.9 | 6.5 | 2.5 | 8.7 | 3.3 | 4.9 |
| 2: 100 N NOV+ | . | 9.2 | 4.5 | 6.9 | . | 7.3 | 2.8 | 5.0 |
| 3: 50 N KAS | . | 14.8 | 6.8 | 10.8 | . | 11.4 | 4.8 | 8.1 |
| 4: 100 N KAS | 6.9 | 13.2 | 7.2 | 9.1 | 3.9 | 10.9 | 5.2 | 6.7 |
| 5: 100 N MAR | 7.1 | 12.8 | 6.2 | 8.7 | 4.2 | 11.4 | 4.3 | 6.6 |
| LSD (95%) | - | - | 1.3 | 1.5 | - | - | 1.0 | 1.4 |


Table A5. Nitrogen balance, SEP 1988 - SEP 1989, kg/ha

| Treatment | N added | N retained | N leached | N _{min} 88 | N _{min} 89 | Balance |
|---------------------------------|---------|------------|-----------|---------------------|---------------------|---------|
| Catch-crop of rye grass: | | | | | | |
| 1A: Basic dress | 30 | -35 | -6 | 10 | -13 | -14 |
| 2A: 50 N SEP | 79 | -47 | -7 | 10 | -14 | 22 |
| 3A: 100 N SEP | 128 | -61 | -6 | 10 | -22 | 50 |
| 4A: 50 N NOV | 79 | -50 | -8 | 10 | -17 | 14 |
| 5A: 100 N NOV | 127 | -64 | -9 | 10 | -23 | 42 |
| 6A: 150 N NOV | 176 | -74 | -18 | 10 | -28 | 67 |
| 7A: 50 N KAS | 80 | -44 | -5 | 10 | -13 | 28 |
| 8A: 100 N KAS | 130 | -58 | -4 | 10 | -14 | 64 |
| 9A: 50 N MAR | 78 | -45 | -5 | 10 | -15 | 24 |
| 10A 100 N MAR | 127 | -61 | -4 | 10 | -18 | 53 |
| 11A 150 N MAR | 175 | -76 | -6 | 10 | -27 | 76 |
| LSD (95 %) | | 4.6 | 5.4 | | 7.9 | |
| Uncropped during winter: | | | | | | |
| 1B: 100 N NOV | 137 | -35 | -99 | 10 | -24 | -10 |
| 2B: 100 N NOV+ | 133 | -35 | -57 | 10 | -22 | 29 |
| 3B: 50 N KAS | 80 | -41 | -31 | 10 | -23 | -5 |
| 4B: 100 N KAS | 130 | -54 | -31 | 10 | -24 | 31 |
| 5B: 100 N MAR | 127 | -55 | -31 | 10 | -29 | 22 |
| LSD (95 %) | | 3.7 | 16.7 | | 9.6 | |

Table A6. Nitrogen balance, SEP 1989 - SEP 1990, kg/ha

| Treatment | N added | N retained | N leached | N _{min} 89 | N _{min} 90 | Balance |
|---------------------------------|---------|------------|-----------|---------------------|---------------------|---------|
| Catch-crop of rye grass: | | | | | | |
| 1A: Basic dress | 30 | -48 | -2 | 13 | -15 | -21 |
| 2A: 50 N SEP | 103 | -64 | -3 | 14 | -19 | 30 |
| 3A: 100 N SEP | 176 | -87 | -10 | 22 | -24 | 77 |
| 4A: 50 N NOV | 96 | -70 | -4 | 17 | -24 | 15 |
| 5A: 100 N NOV | 162 | -77 | -18 | 23 | -21 | 70 |
| 6A: 150 N NOV | 227 | -81 | -48 | 28 | -24 | 102 |
| 7A: 50 N KAS | 80 | -71 | -2 | 13 | -18 | 3 |
| 8A: 100 N KAS | 130 | -97 | -3 | 14 | -24 | 21 |
| 9A: 50 N MAR | 80 | -65 | -2 | 15 | -18 | 10 |
| 10A 100 N MAR | 130 | -90 | -3 | 18 | -26 | 29 |
| 11A 150 N MAR | 180 | -116 | -2 | 27 | -33 | 57 |
| LSD (95 %) | | 5.2 | 8.7 | 7.9 | 5.0 | |
| Uncropped during winter: | | | | | | |
| 1B: 100 N NOV | 162 | -49 | -85 | 24 | -31 | 22 |
| 2B: 100 N NOV+ | 168 | -50 | -64 | 22 | -30 | 47 |
| 3B: 50 N KAS | 80 | -69 | -30 | 23 | -30 | -26 |
| 4B: 100 N KAS | 130 | -94 | -36 | 24 | -29 | -4 |
| 5B: 100 N MAR | 130 | -83 | -40 | 29 | -35 | 2 |
| LSD (95 %) | | 4.5 | 11.5 | 9.6 | 6.3 | |

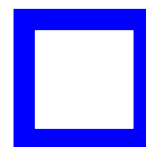


Table A7. Nitrogen balance, SEP 1990 - SEP 1991, kg/ha.

| Treatment | N added | N retained | N leached | N _{min} 90 | N _{min} 91 | Balance |
|---------------------------------|---------|------------|-----------|---------------------|---------------------|---------|
| Catch-crop of rye grass: | | | | | | |
| 1A: Basic dress | 30 | -33 | -5 | 15 | -25 | -17 |
| 2A: 50 N SEP | 81 | -47 | -7 | 19 | -27 | 19 |
| 3A: 100 N SEP | 132 | -57 | -16 | 24 | -35 | 48 |
| 4A: 50 N NOV | 80 | -46 | -15 | 24 | -36 | 7 |
| 5A: 100 N NOV | 129 | -55 | -13 | 21 | -39 | 43 |
| 6A: 150 N NOV | 179 | -60 | -34 | 24 | -43 | 66 |
| 7A: 50 N KAS | 80 | -47 | -7 | 18 | -26 | 17 |
| 8A: 100 N KAS | 130 | -66 | -11 | 24 | -40 | 38 |
| 9A: 50 N MAR | 74 | -44 | -5 | 18 | -28 | 15 |
| 10A 100 N MAR | 119 | -58 | -8 | 26 | -36 | 42 |
| 11A 150 N MAR | 163 | -77 | -10 | 33 | -48 | 61 |
| LSD (95%) | | 4.5 | 9.6 | 5.0 | 8.8 | |
| Uncropped during winter: | | | | | | |
| 1B: 100 N NOV | 129 | -25 | -90 | 31 | -26 | 18 |
| 2B: 100 N NOV+ | 139 | -27 | -91 | 30 | -27 | 23 |
| 3B: 50 N KAS | 80 | -37 | -60 | 30 | -30 | -17 |
| 4B: 100 N KAS | 130 | -48 | -58 | 29 | -38 | 15 |
| 5B: 100 N MAR | 119 | -45 | -68 | 35 | -40 | 0 |
| LSD (95%) | | 3.7 | 10.3 | 6.3 | 8.9 | |

Table A8. Accumulated nitrogen balance, SEP 1988 - SEP 1991, kg/ha.

| Treatment | N added | N retained | N leached | N _{min} 88 | N _{min} 91 | Balance |
|---------------------------------|---------|------------|-----------|---------------------|---------------------|---------|
| Catch-crop of rye grass: | | | | | | |
| 1A: Basic dress | 90 | -116 | -12 | 10 | -25 | -53 |
| 2A: 50 N SEP | 263 | -158 | -17 | 10 | -27 | 70 |
| 3A: 100 N SEP | 436 | -205 | -32 | 10 | -35 | 174 |
| 4A: 50 N NOV | 255 | -166 | -27 | 10 | -36 | 36 |
| 5A: 100 N NOV | 418 | -195 | -39 | 10 | -39 | 155 |
| 6A: 150 N NOV | 582 | -214 | -100 | 10 | -43 | 235 |
| 7A: 50 N KAS | 240 | -162 | -14 | 10 | -26 | 49 |
| 8A: 100 N KAS | 390 | -220 | -18 | 10 | -40 | 122 |
| 9A: 50 N MAR | 232 | -154 | -11 | 10 | -28 | 49 |
| 10A 100 N MAR | 376 | -209 | -16 | 10 | -36 | 125 |
| 11A 150 N MAR | 518 | -268 | -18 | 10 | -48 | 194 |
| LSD (95%) | | 12 | 15 | | 9 | |
| Uncropped during winter: | | | | | | |
| 1B: 100 N NOV | 428 | -108 | -274 | 10 | -26 | 30 |
| 2B: 100 N NOV+ | 440 | -113 | -212 | 10 | -27 | 97 |
| 3B: 50 N KAS | 240 | -148 | -121 | 10 | -30 | -48 |
| 4B: 100 N KAS | 390 | -196 | -125 | 10 | -38 | 41 |
| 5B: 100 N MAR | 376 | -182 | -139 | 10 | -40 | 25 |
| LSD (95%) | | 6 | 22 | | 9 | |

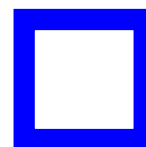


Table A9. Potassium balance, SEP 1988 - SEP 1989, kg/ha

| Treatment | K added | K retained | K leached | K _{min} 88 | K _{min} 89 | Balance |
|---------------------------------|---------|------------|-----------|---------------------|---------------------|---------|
| Catch-crop of rye grass: | | | | | | |
| 1A: Basic dress | 105 | -18 | -36 | 303 | -321 | 33 |
| 2A: 50 N SEP | 138 | -24 | -36 | 303 | -365 | 17 |
| 3A: 100 N SEP | 165 | -30 | -37 | 303 | -376 | 26 |
| 4A: 50 N NOV | 136 | -25 | -34 | 303 | -333 | 47 |
| 5A: 100 N NOV | 160 | -32 | -42 | 303 | -359 | 30 |
| 6A: 150 N NOV | 185 | -37 | -43 | 303 | -409 | 0 |
| 7A: 50 N KAS | 105 | -22 | -32 | 303 | -321 | 33 |
| 8A: 100 N KAS | 105 | -26 | -36 | 303 | -292 | 54 |
| 9A: 50 N MAR | 129 | -22 | -31 | 303 | -339 | 40 |
| 10A 100 N MAR | 148 | -31 | -37 | 303 | -388 | -6 |
| 11A 150 N MAR | 166 | -37 | -40 | 303 | -388 | 4 |
| LSD (95 %) | | 3.6 | 9.1 | | 63.2 | |
| Uncropped during winter: | | | | | | |
| 1B: 100 N NOV | 160 | -19 | -52 | 303 | -363 | 29 |
| 2B: 100 N NOV+ | 163 | -19 | -48 | 303 | -348 | 51 |
| 3B: 50 N KAS | 105 | -21 | -45 | 303 | -331 | 11 |
| 4B: 100 N KAS | 105 | -26 | -45 | 303 | -288 | 49 |
| 5B: 100 N MAR | 148 | -28 | -42 | 303 | -344 | 37 |
| LSD (95 %) | | 1.9 | 9.0 | | 52.0 | |

Table A10. Potassium balance, SEP 1989 - SEP 1990, kg/ha

| Treatment | K added | K retained | K leached | K _{min} 89 | K _{min} 90 | Balance |
|---------------------------------|---------|------------|-----------|---------------------|---------------------|---------|
| Catch-crop of rye grass: | | | | | | |
| 1A: Basic dress | 105 | -47 | -34 | 321 | -366 | -20 |
| 2A: 50 N SEP | 149 | -67 | -36 | 365 | -466 | -54 |
| 3A: 100 N SEP | 187 | -88 | -33 | 376 | -422 | 19 |
| 4A: 50 N NOV | 143 | -72 | -27 | 333 | -431 | -54 |
| 5A: 100 N NOV | 175 | -79 | -38 | 359 | -419 | -3 |
| 6A: 150 N NOV | 207 | -75 | -40 | 409 | -478 | 23 |
| 7A: 50 N KAS | 105 | -74 | -31 | 321 | -318 | 4 |
| 8A: 100 N KAS | 105 | -101 | -28 | 292 | -319 | -51 |
| 9A: 50 N MAR | 139 | -68 | -29 | 339 | -410 | -29 |
| 10A 100 N MAR | 167 | -92 | -29 | 388 | -457 | -22 |
| 11A 150 N MAR | 195 | -114 | -22 | 388 | -491 | -44 |
| LSD (95 %) | | 8.6 | 8.8 | 63.2 | 69.3 | |
| Uncropped during winter: | | | | | | |
| 1B: 100 N NOV | 175 | -50 | -61 | 363 | -471 | -42 |
| 2B: 100 N NOV+ | 175 | -50 | -63 | 348 | -478 | -68 |
| 3B: 50 N KAS | 105 | -71 | -37 | 331 | -354 | -25 |
| 4B: 100 N KAS | 105 | -93 | -34 | 288 | -306 | -39 |
| 5B: 100 N MAR | 167 | -85 | -31 | 344 | -455 | -61 |
| LSD (95 %) | | 4.6 | 21.3 | 52.0 | 38.0 | |

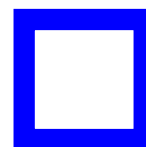


Table A11. Potassium balance, SEP 1990 - SEP 1991, kg/ha.

| Treatment | K added | K retained | K leached | K _{min} 90 | K _{min} 91 | Balance |
|---------------------------------|---------|------------|-----------|---------------------|---------------------|---------|
| Catch-crop of rye grass: | | | | | | |
| 1A: Basic dress | 105 | -19 | -35 | 366 | -376 | 41 |
| 2A: 50 N SEP | 123 | -25 | -41 | 466 | -429 | 94 |
| 3A: 100 N SEP | 135 | -30 | -49 | 422 | -477 | 2 |
| 4A: 50 N NOV | 132 | -25 | -40 | 431 | -405 | 94 |
| 5A: 100 N NOV | 154 | -29 | -46 | 419 | -479 | 20 |
| 6A: 150 N NOV | 176 | -34 | -61 | 478 | -551 | 8 |
| 7A: 50 N KAS | 105 | -24 | -32 | 318 | -366 | 0 |
| 8A: 100 N KAS | 105 | -30 | -29 | 319 | -352 | 13 |
| 9A: 50 N MAR | 124 | -46 | -32 | 410 | -414 | 42 |
| 10A 100 N MAR | 137 | -30 | -30 | 457 | -456 | 78 |
| 11A 150 N MAR | 150 | -41 | -30 | 491 | -506 | 64 |
| LSD (95%) | | 17.9 | 6.2 | 69.3 | 52.1 | |
| Uncropped during winter: | | | | | | |
| 1B: 100 N NOV | 154 | -22 | -79 | 471 | -396 | 127 |
| 2B: 100 N NOV+ | 154 | -22 | -73 | 478 | -398 | 139 |
| 3B: 50 N KAS | 105 | -30 | -41 | 354 | -304 | 84 |
| 4B: 100 N KAS | 105 | -30 | -38 | 306 | -265 | 78 |
| 5B: 100 N MAR | 137 | -41 | -45 | 455 | -384 | 122 |
| LSD (95%) | | 6.3 | 9.6 | 38.0 | 27.5 | |

Table A12. Accumulated potassium balance, SEP 88-SEP 91, kg/ha.

| Treatment | K added | K retained | K leached | K _{min} 88 | K _{min} 91 | Balance |
|---------------------------------|---------|------------|-----------|---------------------|---------------------|---------|
| Catch-crop of rye grass: | | | | | | |
| 1A: Basic dress | 315 | -84 | -104 | 303 | -376 | 54 |
| 2A: 50 N SEP | 410 | -115 | -112 | 303 | -429 | 57 |
| 3A: 100 N SEP | 487 | -148 | -119 | 303 | -477 | 46 |
| 4A: 50 N NOV | 411 | -122 | -101 | 303 | -405 | 86 |
| 5A: 100 N NOV | 489 | -140 | -126 | 303 | -479 | 47 |
| 6A: 150 N NOV | 568 | -146 | -144 | 303 | -551 | 31 |
| 7A: 50 N KAS | 315 | -120 | -95 | 303 | -366 | 37 |
| 8A: 100 N KAS | 315 | -157 | -93 | 303 | -352 | 16 |
| 9A: 50 N MAR | 392 | -136 | -92 | 303 | -414 | 53 |
| 10A 100 N MAR | 452 | -153 | -96 | 303 | -456 | 50 |
| 11A 150 N MAR | 511 | -192 | -92 | 303 | -506 | 24 |
| LSD (95%) | | 17 | 12 | | 52 | |
| Uncropped during winter: | | | | | | |
| 1B: 100 N NOV | 489 | -90 | -192 | 303 | -396 | 113 |
| 2B: 100 N NOV+ | 492 | -90 | -185 | 303 | -398 | 123 |
| 3B: 50 N KAS | 315 | -121 | -123 | 303 | -304 | 70 |
| 4B: 100 N KAS | 315 | -148 | -117 | 303 | -265 | 88 |
| 5B: 100 N MAR | 452 | -154 | -118 | 303 | -384 | 99 |
| LSD (95%) | | 9 | 31 | | 28 | |

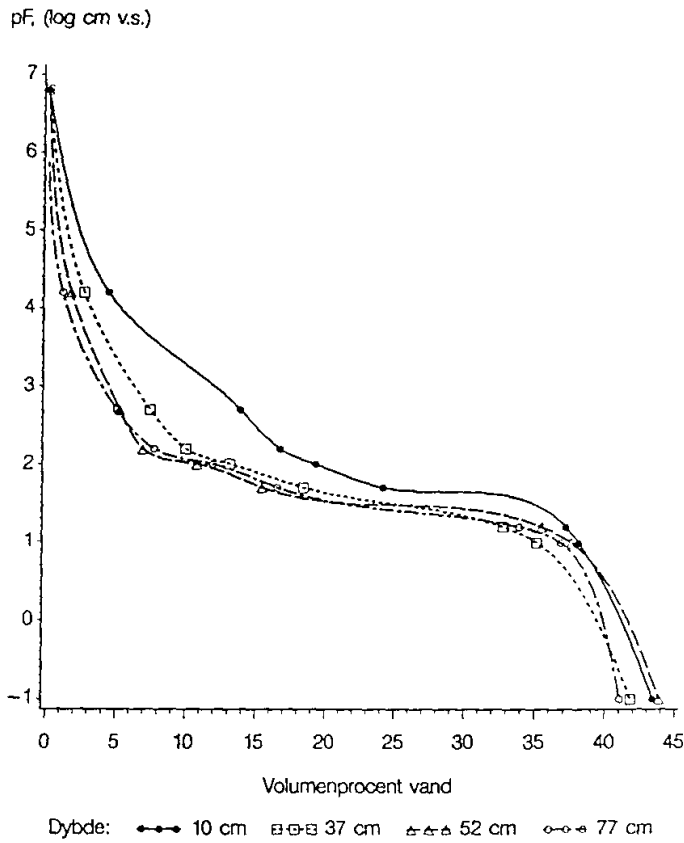
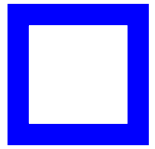


Fig. 1 Retention's curves.
 Volume-percent water versus pF (log cm water column) at different depth.

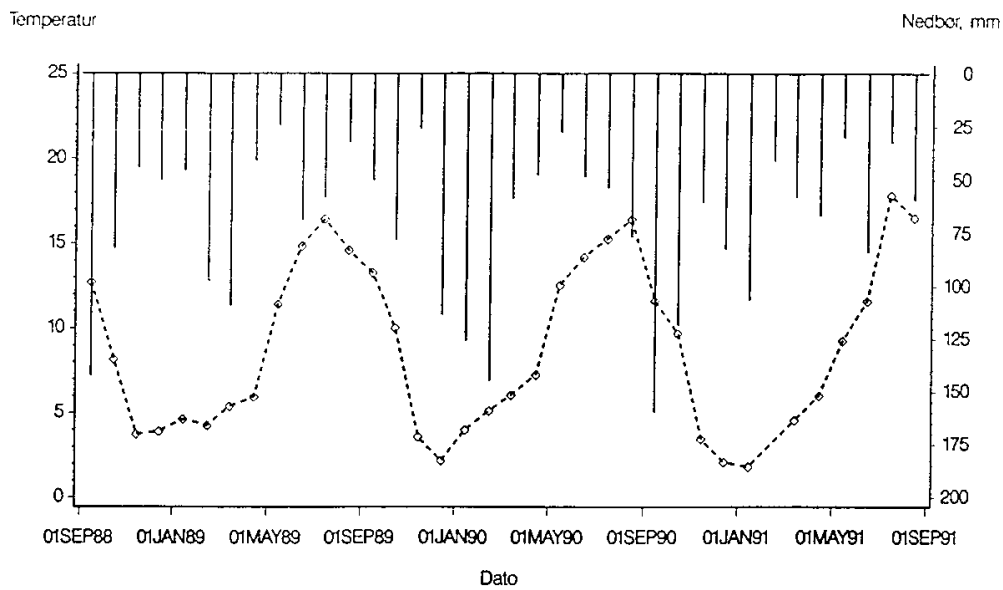
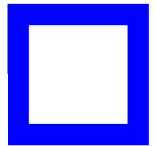


Fig. 2. Average local temperature and rainfall.
 Temperature in Celsius and rainfall in mm versus time. The observations are averaged monthly.



Overskud/underskud, mm

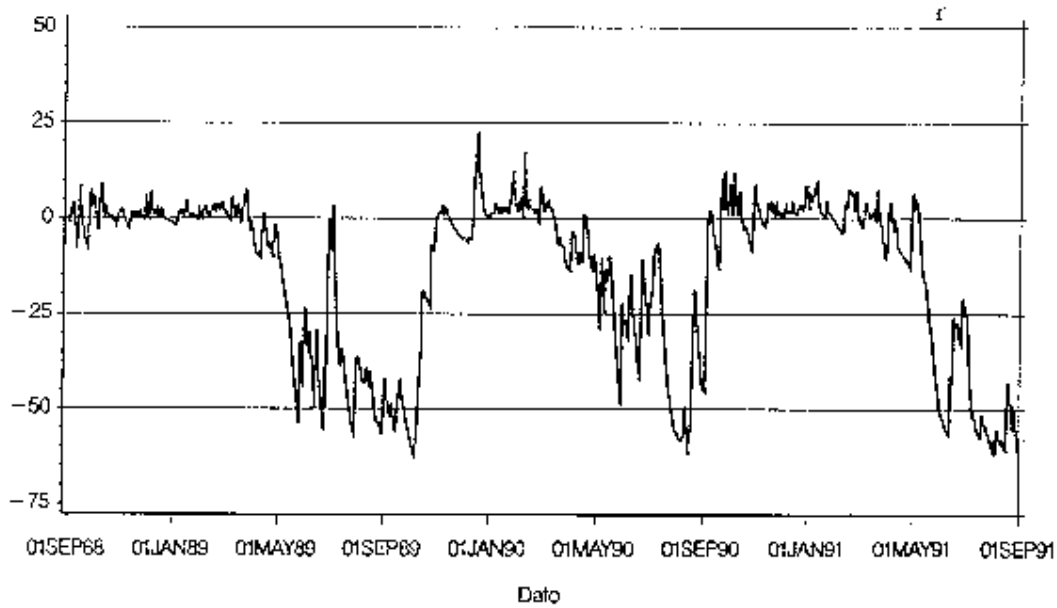


Fig. 3 The water contents of the root zone.
 The water content of the root zone versus field capacity (surplus/deficit, mm) over time.
 The crop is spring barley with ray grass catch crop.

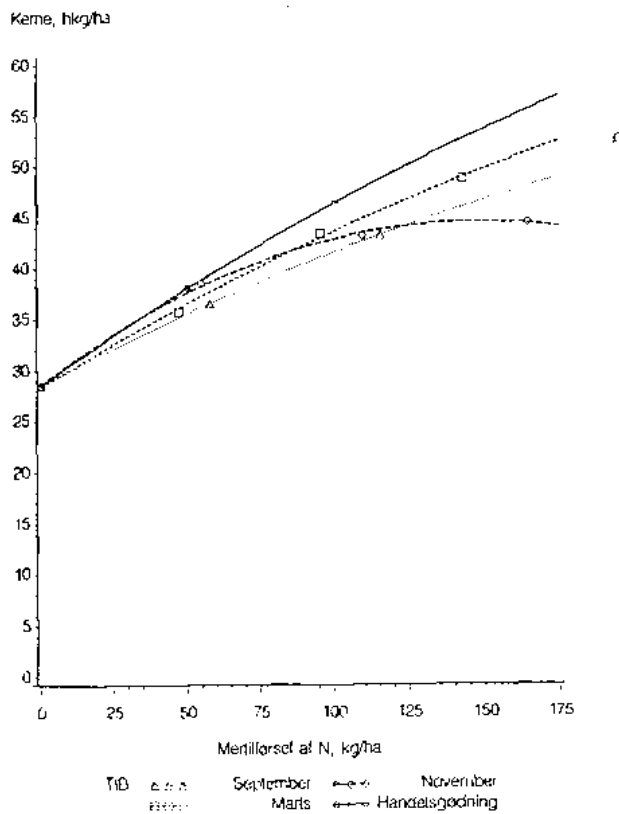


Fig. 4. Grain yields hkg/ha versus quantity of potato juice.
 The plots have all received 30 kg N per ha as artificial fertilizer + additional 50, 100 or 150 kg as potato juice.

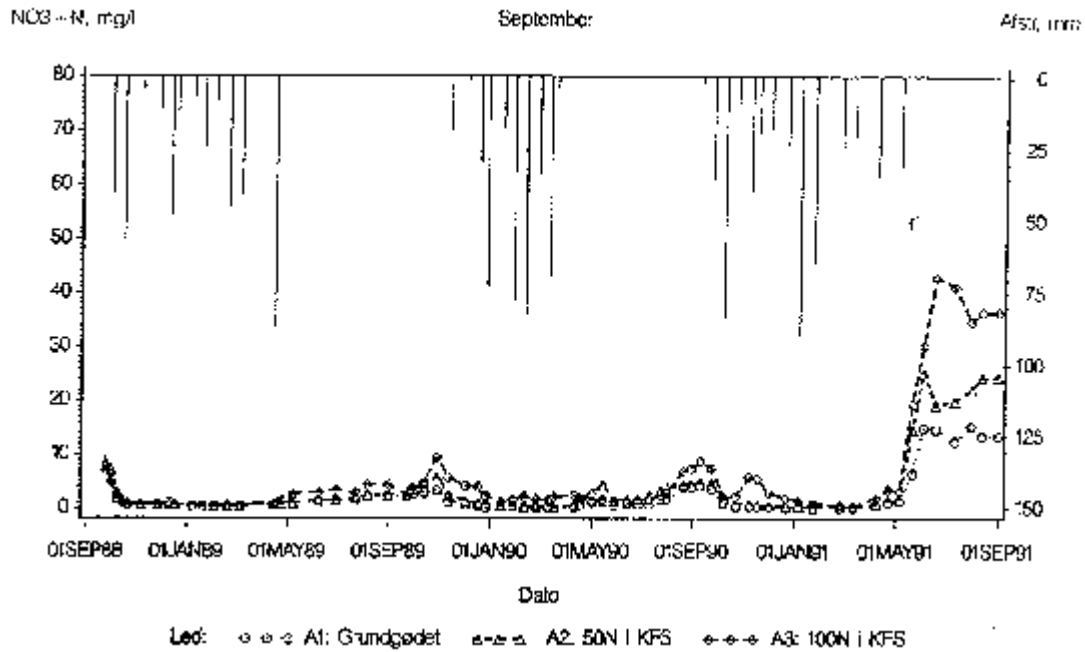
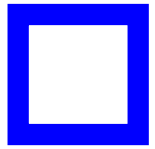


Fig. 5a. Nitrate concentration in soil water

Concentrations of nitrate nitrogen mg/l 80 cm below surface and calculated drain of water in mm. All plots with rye grass as catch crop.

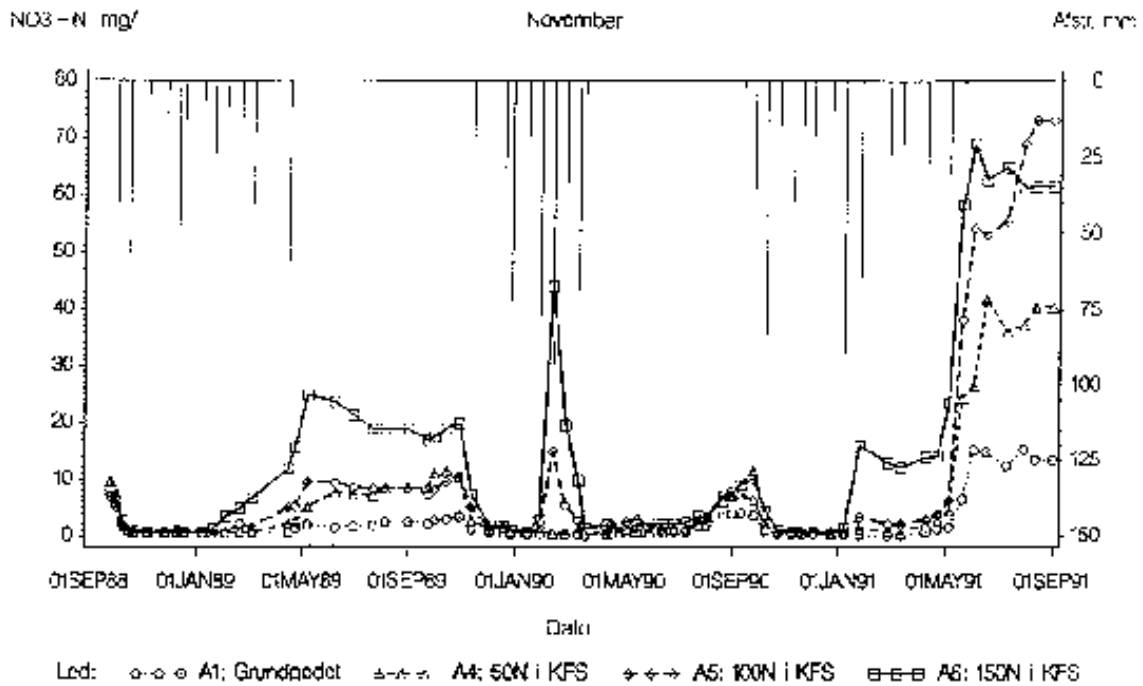


Fig. 5b. Concentration of nitrate in soil water.

The graph shows the effect of potato juice given in November.

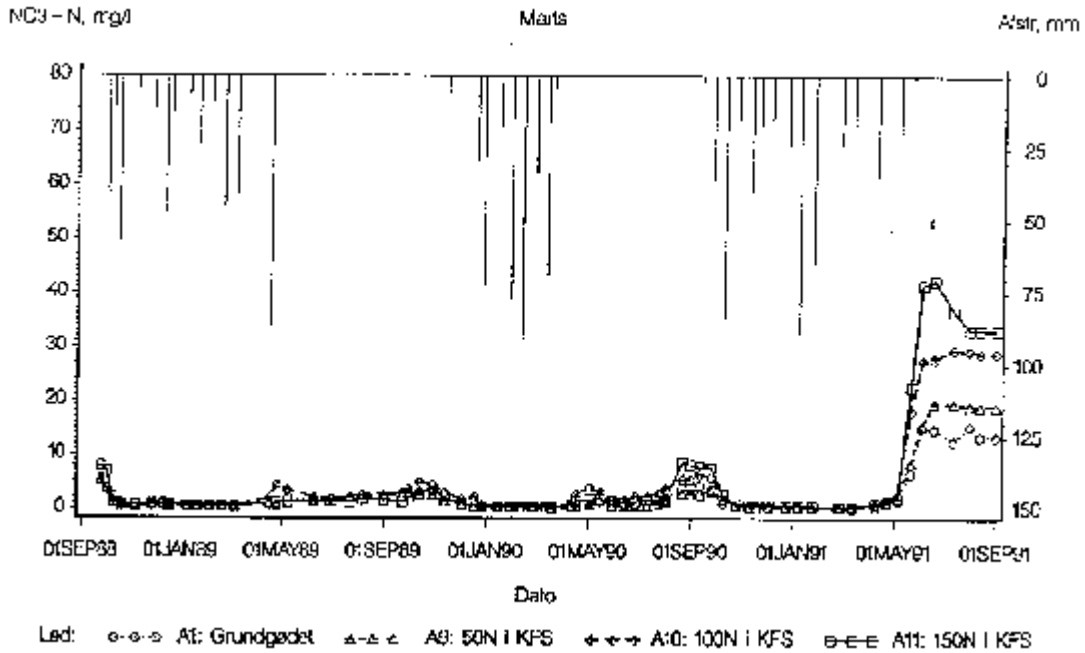
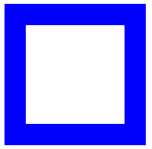


Fig. 5c. Concentration of nitrogen in soil water.
 The effect of potato juice in March before sowing spring barley after rye grass catch crop.

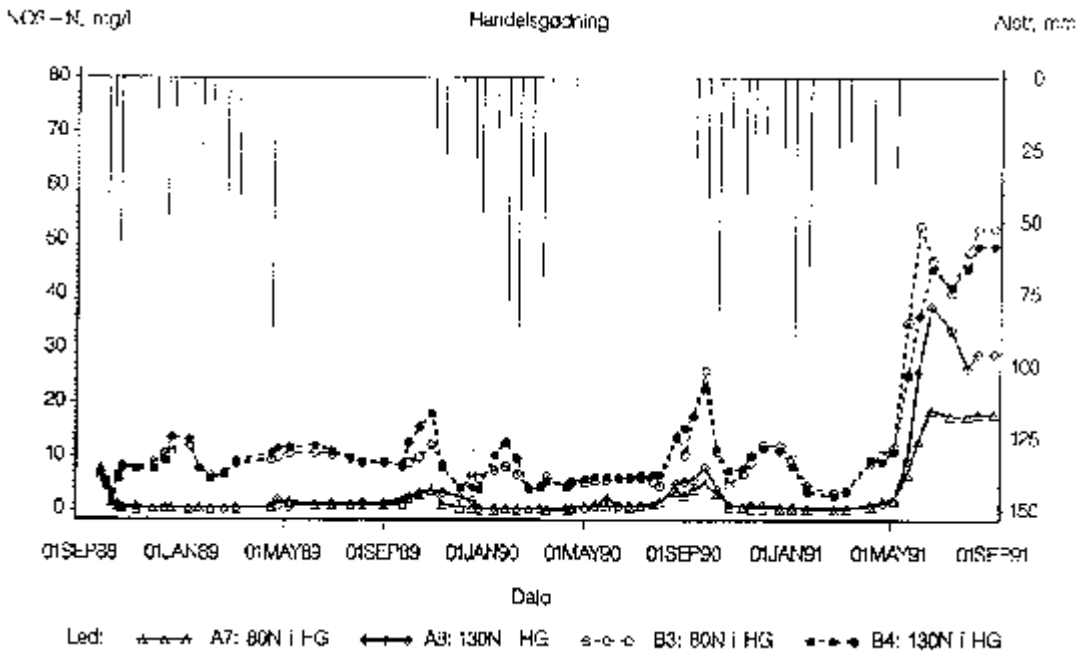


Fig. 5d. Concentration of nitrogen in soil water.
 The effect of artificial fertilizer in March.
 Group A is with spring barley after rye grass catch crop and group B is spring barley after uncropped fields.

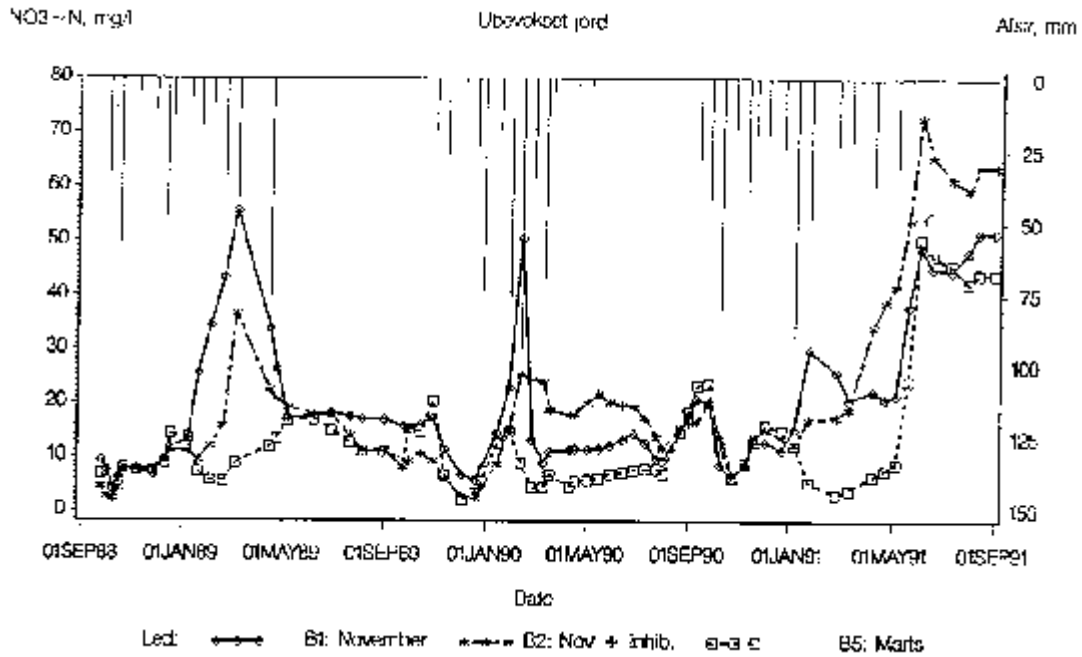
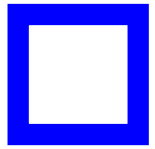


Fig. 5e. Concentration of nitrate in soil water.
 The effect of potato juice on uncropped soil during winter. B2 is test of potato juice with nitrification inhibitor.

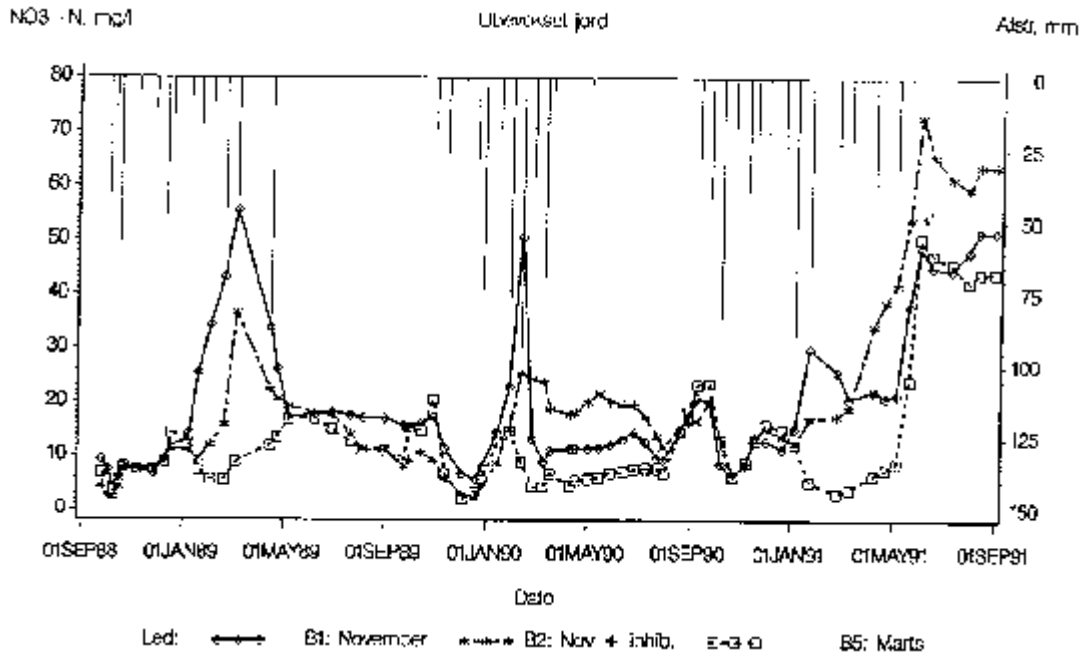


Fig. 5f. Concentration of nitrate in soil water.
 The effect of potato juice equivalent to 100 kg N/ha on rye grass catch crop at different time.

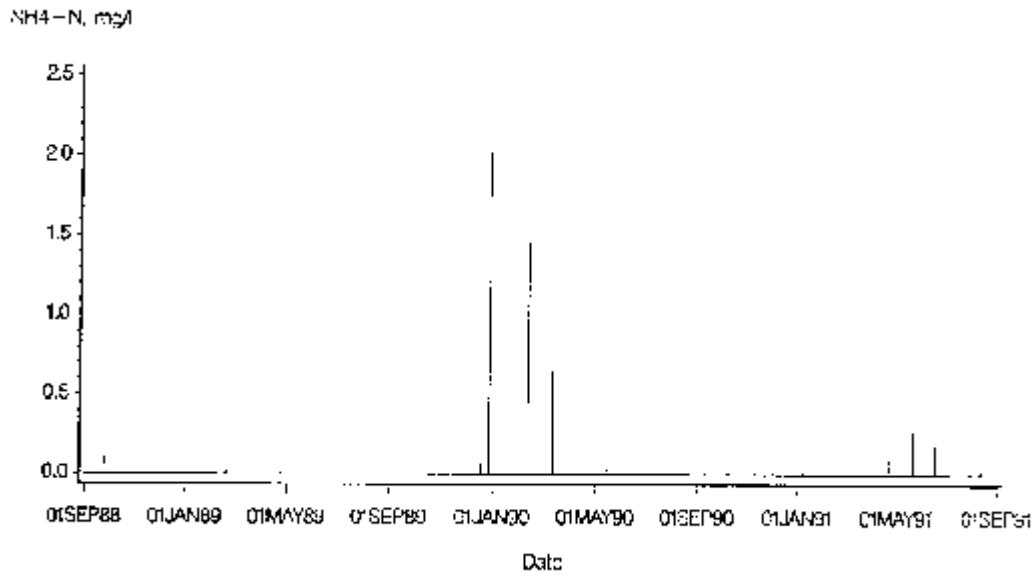
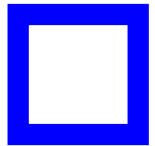


Fig. 6 Concentration of ammonium in soil water.
 The concentration of ammonium nitrogen 80 cm below surface after potato juice with nitrification inhibitor (100 kg N/ha).

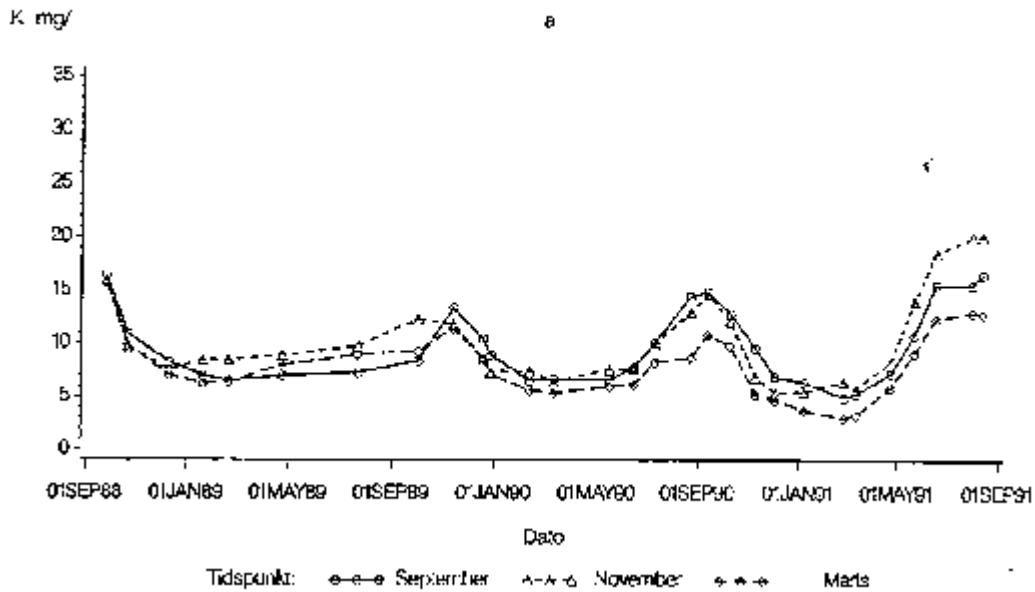


Fig. 7a. Concentration of potassium in soil water.
 The effects on potassium concentration mg/l in soil water 80 cm below surface versus time of application. Graph shows joint results of 50 and 100 kg N/ha.

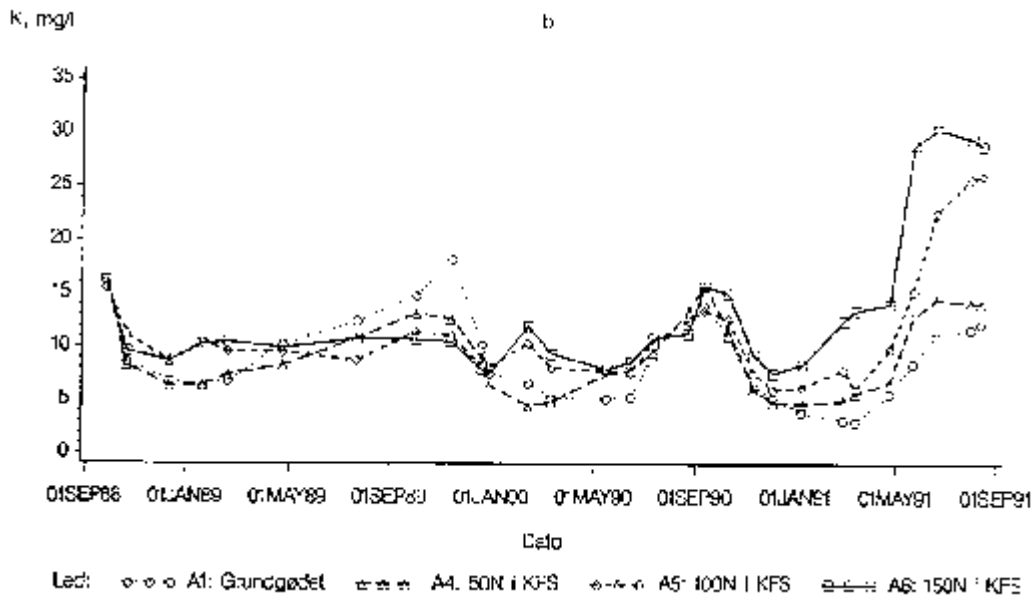
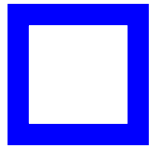


Fig. 7b. Concentration of potassium in soil water. Potassium concentration (K mg/l) after different quantities of potato juice in November on rye grass catch crop. A1 did not receive potato juice.

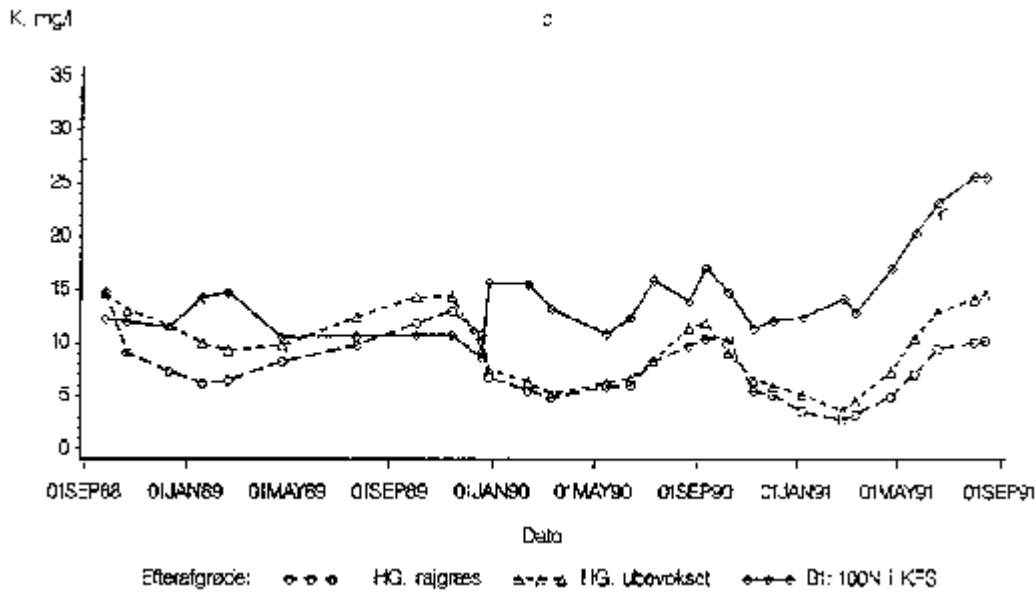


Fig. 7c. Concentration of potassium in soil water. The effect of artificial fertilizer in March and potato juice (100 kg N/ha) in November. HG = average of two levels of artificial fertilizer.

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