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NITROGEN PREDICTION FOR VEGETABLE CROPS IN GERMANY

STUDY TOUR REPORT

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FV89 STUDY TOUR TO GERMANY, 4-18 MAY 1991

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Objective

To obtain information to help in the development of more accurate nitrogen testing and N prediction systems for field vegetables. This tour was undertaken with Dr Alan Scaife, HRI Wellesbourne whose aim was to develop collaborative links between Wellesbourne and research units within West Germany.

Itinerary

Date	Visit
4 May	Depart Kirton to Germany
5 May	Arrive Bremervorde
6 May	Dr A Nitsch, Landwirtschaftskammer, Bremervorde
7 May	Prof A Schenk, Institute of Plant Nutrition, Hanover
7 May	Prof H C Scharf, Horticultural Teaching and Experimental Station, Ahlem, Hanover
8 May	Prof A Jungk, Plant Nutrition Department, University of Gottingen
8 May	Dr L Luchtrath, Seminar Fur Landwirtschafflice, Gottingen
9 May	Travel to Regensburg
10 May	Prof Tanner, Department of Cell Biology, University of Regensburg
11 May	Travel to Schwaeb Gmund
12 May	Travel to Stuttgart
13 May	Prof Marschner, Institute of Plant Nutrition, University of Hohenheim
13 May	Dr Ernst, University School of Horticulture, Hohenheim
14 May	Mr Schwemmer, State Horticultural Teaching and Experimental Station, Heidelberg
14 May	Prof Schaller, Geiseheim Horticultural Research Station
15 May	Dr Lorenz, Institute for Horticulture, Neustadt
16 May	Travel to Ghent
17 May	Dr G Hofman, Dr P Demyttenaere, Department of Agricultural Soil Science, University of Ghent And return to UK via Zeebrugge
18 May	Return to Kirton

Conclusions

One of the primary driving forces behind improvements in N recommendation systems for vegetables in Germany is the need to reduce nitrate in drinking water.

In drinking water protection zones, very tight limits on the levels of autumn soil mineral nitrogen have been set. These are likely to be difficult to meet with some vegetable crops but improvements to fertiliser prediction are being made in an attempt to meet the limits.

The highlight of the tour from an N prediction point of view was the visit to the Horticulture Advisory Service in Neustadt, where we met some of the team who developed the "Kulturbegleitenden Nmin Sollwerte" (KNS) system for N recommendations for vegetable crops.

The system seems to be widely used throughout Germany and forms the basis of recommendation systems in both Holland and Belgium.

The KNS system is being further developed by Prof H C Scharpf and Herr Fink at the Horticultural and Teaching Experimental Station at Ahlem near Hanover, Germany. The 'N Expert' system is being developed for IBM PCs to replace the look up tables of the KNS system.

The N expert system and the KNS system differ from Duncan Greenwood's model in that they are based on broad correlations in data from field experiments. Greenwood's dynamic model is mechanistic in character and is likely to have advantages especially where there is a likelihood of nitrate leaching during the growing season. The model can account for differences in planting date, spacings or cultural practices. Greenwood's model could also have advantages in that it will reduce the need for repetitive measurements of soil mineral N. Both programmes are being made more user friendly and need to be carefully compared with ADAS models under UK conditions. This provides an excellent opportunity for Tripartite exchange of data, modelling, and advisory experience between HRI Wellesbourne, ADAS Kirton and Hanover.

One of the needs in the KNS and N expert system is the need to take soil samples for mineral N analysis 3-4 weeks after planting. In Germany there are many laboratories, private and Government, providing facilities for analysis of soil mineral N. It is essential to have a turn-round time of no more than 1 or 2 days between sampling and reporting the recommendations whilst the crops are waiting for the fertiliser applications. It is also essential to ensure that costs of measurement is less than the benefits in fertiliser saved.

A number of scientists who we visited had investigated the use of sap testing for predicting nitrogen requirement. In practice, the test was found to be of limited use except to test produce nitrate contents before harvesting.

Recommendations

ADAS should:-

1) Maintain contacts with Lorenz, and Maync at Neustadt and Scharpf in Hanover to pool experiences on the use of soil mineral N for vegetable crops.

2) Select the most appropriate user friendly model for the interpretation of soil mineral N data.

3) Improve turn around times and availability of the ADAS soil mineral N service for growers of vegetable crops in the United Kingdom.

WATER PROTECTION ZONES

The need to reduce nitrate in drinking water is one of the primary driving forces behind improvements in German N recommendation systems. This is particularly so in water protection zones. I spoke with Dr Ludwick Luchtrath (Gottingen) about the ways Germany was approaching its nitrate problems.

Vulnerable areas are defined as water protection zones and these were split into 3 areas, Zone 1 closest to the water source, Zone II defined as within 2 days percolation of the source, and Zone III where the water takes longer to reach the water source. The limits on farming depend on proximity to the centre. In Zone 1 no conventional agriculture is permitted, there are severe restrictions in zone II, and in zone III there are limits to the use of pesticides.

The penalty for infringing any of the pollution laws in these zones is a fine of 50,000DM(£17,241). The aim is to reduce the 0-90cm autumn soil mineral nitrogen level to 45kg/ha. This level is not enforced at the moment but in the future it may be. The national pollution law states that farmers will be compensated for any loss in yield. However, there are difficulties in deciding how this should be funded. In Baden Wurttenberg there is a "water phenneg", a tax on the quantity of water consumed. In other lander there is resistance to paying a water tax.

To claim compensation for yield loss farmers will have to provide complete records of their crop management. Many companies are producing extensive data base systems for this purpose at a considerable cost. The extension service was trying to devise a simple recording system for farmers. In some parts of Germany farming groups and the water companies are jointly developing computer programmes for this purpose.

There are different levels of advice given to farmers in these zones. In some fertiliser recommendations are based on the level of soil mineral nitrogen residues. In other areas advice is not given until the water nitrate concentration reaches 50mg/l. There is considerable discussion as to how these water protection zones will work in practice.

Most of the recommendations for vegetables are based on soil mineral N measurements, rather than on sap testing. Sap testing is not used because of the high variability in sap nitrate content between sampling positions on plants and the time when the samples are taken. Sap tests are only used to monitor nitrate content in green vegetables at harvest.

A large number of fields are sampled in the water protection zones of Rhineland PFalz to provide seasonal monitoring of soil mineral nitrogen levels. The measurements of soil mineral nitrogen, are based on a minimum of 10 cores/ha taken at 0-30, 30-60, 60-90cm depth. These measurements do not enable field specific recommendations to be given for different crops but allow advisers to have a general idea of seasonal variations in mineralisation and over winter losses of N through leaching.

In Heidelberg we met Mr Schwemmer from the State Horticultural Teaching Station and Experimental Station. He described the fertiliser policy for crops within Baden Wurttenberg.

In the water protection zones N fertilisation is reduced by 20% from that recommended for maximum yield. To check the performance of this policy and to make sure that growers follow these guidelines soil mineral N levels are checked between the 15 November and the 15 December. At this time 200,000 samples are taken for analysis from fields within the water protection zones. The state analytical service (VDLAUFA) can analyse about 3000 samples a day using calcium chloride extracts measuring nitrate with the flame photometer method. If the level of mineral nitrogen exceeds 45kg/ha a penalty is imposed. The grower has to pay back the compensation that he received for loss of yield. In the autumn of 1991 the compensation given to growers amounted to 310DM/ha (£107/ha). If the growers can prove larger financial loss they receive a higher level of compensation.

It was agreed that vegetable crops, even with good fertiliser practice, would be unlikely to leave less than 45kg/ha nitrate N. However there were reference areas set up representing different soils and cropping rotations. Fertiliser applications would be reduced by 20% from those recommended by the KNS system (see later). If these reference points had soil mineral N Levels in excess of 45kg/ha then some extra allowances would be made. One of the measures used to help reduce nitrate residues from vegetable crops is to avoid incorporation of crop residues before the 15 December. Experiments had shown that early ploughing, even after removal of residues, caused higher levels of nitrate in spring than if incorporation of crop residues was delayed until the 15 December.

Nitrate was also measured in glasshouse soils and found in many cases to be in excess of 1000kg/ha to 90cm and in one or two cases 5000kg/ha. The regulations for glasshouse crops will be that the soil mineral N to 90cm should not exceed 180kg/ha N. Glasshouse growers will be given a grant of up to 60 per cent of the cost of a system to recycle drainage water. An alternative approach would be to use recycling Rockwool or NFT.

In Hohenheim I spoke to Dr Ernst who was investigating methods of reducing inputs to crops in water protection zones. For example, in order to overcome the need to use herbicides black polyethylene or paper sheets have been tested. To reduce pest attack the use of nets was being investigated. Mineralisation rates of nitrogen under these systems were likely to be higher than in normal soils and modifications would have to be made to the estimates of nitrogen supply from the soil. Another problem with the use of soil covers for later planted crops is the supply of water. I saw some plots where they had successfully used lay flat tubing underneath the paper or plastic cover to provide water. This irrigation system seemed to be satisfactory for small holdings but inappropriate for the large scale horticulture production of England and Wales.

In an attempt to reduce nitrate leaching and improve the uptake of fertiliser nitrogen, the application of Osmocote granules at reduced rates under these covers were being tested. Though it is a very expensive fertiliser Dr Ernst felt that they could reduce the quantity of nitrogen applied. They had developed a machine to drop Osmocote pellets just beneath the modules. This was the first year of the trial so results were not available.

Dr Ernst also described further restrictions that applied to growers in the Zone II water protection areas. In these areas soil mineral nitrogen levels were checked on all holdings between the 15 November and the 15 December. If the levels to 90cm were greater than 45kg/ha compensation for loss of yield would be withheld unless there was a good reason. In 1992 there will be even more severe penalties for growers who exceed 180kg/ha nitrogen level.

An example of extensive Research and Development was the Reinshof Extensification experiment near Gottingen. This new experiment on a brickearth soil is designed to examine long term effects of reduced pesticide and fertiliser inputs on crop yield and the environment. The possible interaction between pesticide requirement and levels of soil nitrate will be studied. The ecology of treatment plots will be monitored, ie the earthworms, insect and the weed populations. This project was being undertaken by 10 different departments in the University of Gottingen and shows the advantages of good co-operation between different disciplines. Different levels of management will be applied to blocks of land, large enough to support independent populations of animals with limited mobility. One block of the experiment will receive commercial levels of agrochemicals. Nitrogen fertiliser rate will be determined by the level of soil mineral nitrogen. The rotation is rape seed, winter wheat and winter barley. Additional blocks will receive 30 or 50 per cent less nitrogen and pesticides will be applied at threshold values.

The intensive programme of monitoring will include nitrate in drainage water using porous pots, mineral nitrogen on a 4-6 weekly basis, plant growth, rainfall, and nitrate in the crops. Porous cups are placed at 80cm, 120cm and 160cm depth. One interesting problem is that they were finding nitrate in the 80cm porous cups but not in the 160cm porous cups. This poses the question of whether biological processes are removing the nitrate below 80cm, or if the finding is just an artifact of the measuring system. The effect of different practices on the mineralisation rates of crop residues, and soil organic matter are being monitored. One interesting finding was that the lowest residues of nitrogen were not always where fertiliser had been omitted. The explanation is that unfertilised plants are smaller and so remove less of the nitrogen.

This experiment was also being repeated at a further 2 sites on different soil types.

FERTILISER RECOMMENDATION SYSTEMS

The "kulturbegleitenden Nmin sollwerte" KNS system

The highlight of the tour from an N prediction point of view was the visit to the Horticulture Advisory Service in Neustadt, where we met some of the team who developed the "Kulturbegleitenden Nmin Sollwerte" (KNS) system of N recommendations for vegetable crops. KNS was based on experimental work carried out by Bohmer, Scharpf and Wehrmann in Hanover.

KNS seems to be widely used throughout Germany and forms the basis of recommendation systems in both Holland and Belgium. Measurements of soil mineral N are made at different stages during crop growth. At planting look-up tables indicate the "should-be" or "sollwerte" value for the crop.

N recommendation = "sollwerte" - soil mineral N to rooting depth

Fertiliser N should then satisfy early crop needs, a second measurement of soil mineral N is made three to four weeks after planting. Allowances are then made for N in the crop, and mineral N in the soil to rooting depth. The fertiliser needed to satisfy crop needs until harvest is then decided by the use of another "sollwerte" value. Look-up tables are also available to estimate N release from previously incorporated crop residues and from the soil organic matter. An example of the 'KNS' system for summer lettuce is shown in Table 1:

This system was initially used for vegetable crops but some arable farmers are also taking it up. One of the problems the advisers are finding is convincing growers that it is actually worthwhile. The standard area for each vegetable crop in the Neustadt area is only one-third of a hectare so it needs a saving of 50kg/ha to pay for the analysis of soil mineral N in the fields. They are convincing farmers of the need to use this service by setting up demonstration plots on farms with a range of crops. Convincing growers of the need to measure soil mineral nitrogen is easier for crops where quality is an important factor such as kelps for canning, sugar beet, onions for storage and potatoes, especially for chipping.

Table 1: KNS System for Summer Lettuce

		1	2	3	4	5	6/E
(1) Summer cultivation	(5) Weeks' cultivation + harvest →	1	2	3	4	5	6/E
(2) Planting: May-July	(6) Requirements = 100kg N/ha →	0	5	15	30	50	0
(3) Specimen variety: Ovation (4) 10 plants/m² (18)	(7) Minimum supply kg N/ha →	40--------------------------------->					
(8) Nominal values of kg N/ha for measurement at planting + week 3		45(9)		135(10)			
(11) Root depth (cm) during supply period		30					

(12) Nitrogen balance: Growth: 600dt/ha = 100kg N/ha,
harvest: 400dt/ha = 70kg N/ha, crop remains: 200dt/ha = 300kg N/ha.

Key to Table 1:

1) Summer cultivation: Time of year at which the vegetable is cultivated.
2) Planting: Depending on the variety/season, direct drilling or planting. Then the actual date or period.
3) Specimen variety: The nitrogen balance and the period of cultivation relate to the specified variety.
4) 10 plants/m² (18): The data given indicate 10 plants per m² and the head size "18".
5) Weeks' cultivation + harvest: The period of cultivation varies according to the species, variety, cultivation method or date of planting; it is given as weeks, half-months or months. Harvest periods are marked "E" [= Ernte/harvest]. For lettuces planted in summer, the growing time is 5 weeks. They are harvested at the start of the sixth week.
6) Requirement = 100kg N/ha: The figure given is the N requirement per week, amounting to a requirement of 100kg N/ha for the entire crop. There is a clear increase in the N-uptake to 50kg N/ha per week of by the end of cultivation.
7) Minimum supply kg N/ha: For a reliable N supply, a certain minimum supply of N is needed. The minimum amount specified applies until the end of cultivation and for the specified root depth.
8) Nominal values kg N/ha for measurement at planting + week 3: This indicates what the nitrogen supply should be at a particular time. The example given is for measurement at planting + week 3 of cultivation.
9) 45kg N/ha: The nominal value is calculated from the requirement in the first 2 weeks (0 + 5kg N/ha) plus the minimum supply of 40kg N/ha at the end of cultivation.

10) 135kg N/ha: The nominal value is calculated from the requirement in weeks 3-5 (15 + 30 + 50kg N/ha) plus the minimum supply of 40kg N/ha at the end of cultivation. However, the KNS system allows the nominal value to be calculated for any date. For example, if at the start of the fourth week of cultivation a heavy storm results in severe nitrogen displacement, an additional Nmin measurement is needed. The new nominal value is then calculated as follows: requirement for the fourth and fifth weeks (30 + 50kg N/ha) plus minimum supply at the end of cultivation (40kg N/ha) gives a nominal value of 120kg N/ha.

11) Root depth (cm) during the supply period: It is known from experience that vegetable roots can penetrate the soil to a depth of up to 90cm. Measurements of nitrogen are to be made in the soil layers reached by the end of a particular stage in cultivation. With lettuce, the figure is 30cm until the end of cultivation. The soil sample is to be taken from the depth which it is thought the roots might reach by the next measurement or by the end of cultivation.

12) Nitrogen balance: 600 dt plant mass containing 100kg N grow on one ha. Of the total plant growth, 400 dt is taken from the field, leaving 200 dt crop remains. The 30kg N which they contain is again available for subsequent crops. If a higher or lower figure is expected for total growth, all the specified N values must be adjusted accordingly.

Most farmers apply a small quantity of fertiliser at planting and then measure soil mineral N after 4 weeks just before the period of maximum growth. Rapid reporting then allows recommendations to be given for a nitrogen top dressing. Measuring soil mineral nitrogen at this stage ensures a reasonable allowance is made for N mineralised from previously incorporated crop residues.

N Expert system

The KNS system is being further developed by Prof H C Scharpf and Herr Fink at the Horticultural and Teaching Experimental Station at Ahlem near Hanover, Germany. Herr Fink is developing the 'N expert', an expert system for IBM PCs written in Pascal.

This system replaces the look up tables of the KNS system, and should save time. The system will be able to make allowances for crop residues, rainfall, soil type, rooting depth, and soil mineral N at all stages of crop growth.

The 'N expert' system is a synthesis of the KNS system with results from field experimental research both in Hanover and in other parts of Germany.

The aim is to produce a package that may be used by growers and advisers. The model has very simple inputs, such as previous crop, rainfall, soil type, rooting depth, and soil mineral N . If data is unavailable there are many default values that could be used. 'N expert' would store the cropping and N recommendations on file for each field.

Recommendations are available for a range of some 40 crops with various dates of planting but is only suitable for single season crops. The programme will list the reasons behind the individual recommendations. The system is still being developed and tested. It is hoped that copies of 'N expert' will become available for testing under UK conditions.

SOIL MINERAL NITROGEN

The level of sophistication of methods for measuring soil mineral N varied from quick field based tests to routine full scale analytical procedures.

The quickest and simplest test was shown to us by Nitsch (Bremervorde). This involved the use of specially designed soil sampling equipment. They would take 15 0-30cm cores in each field. The cores are shaken with water, or on clay soils with calcium chloride, to extract the nitrate. The nitrate level in the extract is measured using Merk Nitrate testing strips.

We visited a laboratory near Heidelberg in the middle of an area of intensive horticultural production on brick earth soils. The laboratory provides a sampling and analysis service for the locality. If a grower requests a field to be sampled in the morning the results and recommendations could be available at midday or in very busy times the next day. Some growers are very enthusiastic and regularly monitor the levels of soil mineral N in their soil, but even though analysis and sampling are provided free of charge nearly 50 per cent of the growers do not use this system.

As soon as the samples are received into the labs the soil is mixed in a bucket, passed through a 6mm sieve and then 250 grams of soil is added to 250 mls of deionised water. Deionised water was used rather than calcium chloride to avoid interference from the chloride ion. After mixing and filtering, nitrate is determined in the filtrate using Merk strips and a reflectometer. The dry matter content of the soil is determined by drying it in an oven for two hours at 105 degrees C. Recommendations for fertiliser additions are given according to the 'KNS' system.

<u>BOLAP - Soil Analysis and Recommendation Service</u>

This facility was set up 3 years ago in Neustadt. The lab used to process about 30-40 mineral N samples per day this has now risen to 250 per day. They guarantee a 2 day turn-round time, including sampling.

Analysis and recommendations cost:-

16DM (£5.51) per layer for analysis only

27DM (£9.31) for analysis and sampling per layer

This is in fact more expensive than the official Government service (LAUFA) but the Government laboratory can take up to 3 weeks to provide the results which is too slow for providing recommendations for vegetables. At the moment BOLAP is being subsidised by the Government to the extent of 50 per cent of the analysis cost. If this subsidy was removed the testing service would not be viable except in the water protection zones where it is obligatory.

Soils are sampled in the field using modified wood boring bits attached to a BOSH Electric Screwdriver. This technique enabled samples to be taken to a depth of 90cm on the loamy sand soils of the area with great speed.

Soils are normally taken back to the laboratory for analysis. Some earlier attempts were made to do the analysis in the field but this gave inaccurate results. In the lab samples are analysed using calcium chloride extracts and colorometric methods to determine nitrate. The results are interpreted using the KNS system.

SAP TESTING

Dr Nitsch at Bremervorde found that measurements of soil mineral N on its own gave unreliable fertiliser recommendations where levels were less than 80kg/ha. Nitsch had developed a system based on soil mineral N to decide on early nitrogen applications and later sap testing to decide whether extra fertiliser nitrogen is needed. This system was devised for maize wheat, barley and potato crops.

Sap nitrate levels were found to vary considerably during the day, being much lower after mid-day. Consequently sampling time was standardised on early morning. Nitsch also found considerable variation in tissue nitrate content between leaves on different parts of the plant. All measurements were therefore made on a 1cm long sample of the stem base from 30 plants.

Nitsch indicated that sap tests become unreliable when dry conditions, restrict N uptake. Nitsch requires that growers keep good records of rainfall in order to give some indication of the availability of nitrogen which had already been applied. In dry conditions a measurement of mineral N in the surface is recommended to check that there is sufficient available mineral nitrogen in the soil.

A large number of experiments had been set up in the area to assess seasonal variations in sap nitrate content. Sap nitrate levels were being measured on a regular basis on a range of crops with different levels of applied nitrogen.

The interpretation of the sap test depends to a large extent on experience rather than the use of a computer model or a scientific system. Provided the sap nitrate concentrations are in excess of the critical concentrations then no fertiliser would be recommended. If the nitrate concentrations are lower than this value an application of N would be recommended with its rate based on the soil type, crop growth stage, and rainfall.

Despite the considerable work put into devising this system not as many growers were using this as Dr Nitsch wished. There was some interest in testing nitrate levels in produce. Potato tuber nitrate levels at harvest of greater than 100ppm nitrate are taken as an indication of over use of fertiliser. High nitrate content in tubers were said to be associated with flouriness and poor cooking quality and is used by companies as a criteria for rejection of samples.

Some work had also been carried out comparing conventional and slow release fertilisers. Where slow release fertiliser had been applied in the form of Alzon the level of nitrate in the sap was lower for the same level of dry matter compared with conventionally fertilised plots.

We also spoke to Dr Shultz in Hohenheim who was working on sap tests for fertilising of cereals. Dr Shultz explained that in Lower Saxony it was claimed that by using test strips you could reduce the fertilisation for winter wheat from 240kg/ha to 160kg/ha. As the system had been standardised in the north could it be modified to suit Southern Germany? It is a simple system based on a Kodling sap test method which places samples in 1 of 4 categories depending on the colour change of 30 stem bases crushed between two glass plates. Determinations are made at a number of growth stages. The Kit costs only 54DM (£18.60) excluding reagents. One of the reagents needed is concentrated sulphuric acid which is unlikely to be approved for use in the UK. The alternative is to use Merk test strips but this involves dilution of the sap. Dr Scaife (Wellesbourne) mentioned an alternative way of measuring sap concentration with Merk strips avoiding dilution which uses the speed of colour development. Dr Barbera Geyer (Hohenheim) compared the Merk and Kodling systems and found a good correlation between them. One problem she found with sap testing on maize experiments was the crop decimation caused by removing so many stem bases! She was therefore investigating the use of leaf sheaths and blades. We asked how many growers were using sap testing in the area. The answer was very few if any!

FERTILISER EFFICIENCY

We visited a number of scientists who were investigating ammonification losses from fertilisers and slurries.

One of the students at the University of Gottingen, Mr Ladewig was investigating the losses of ammonia from urea. This work was carried out in controlled environment conditions with reconstituted soil cores. It gave some very useful pointers to the factors affecting urea loss on agricultural soils.

The main factors influencing the loss of urea included pH, moisture content, soil buffer capacity and the temperature of the soil. Ammonia losses from Urea over a 30 day period amounted to 0.06% at 4°C, 1.6% at 14°C and up to 32% at 25 C. At 4°C urea was still detected 28 days after the application of 100kg/ha of urea. More ammonia was lost from dry soils, at 7% moisture content 15% was lost, at 17% moisture content only 2% was lost over a 20 day period. Ammonia could still be lost from sandy soils; of pH 5.5 if microsites of higher pH developed around urea prills. Incorporation of fertiliser even 2cm below the soil surface could reduce ammonia losses substantially. Ladewig intended to develop a model to explain ammonia volatilisation in the laboratory which would be extended to field conditions.

Dr Barbera Geyer at Hohenheim is studying nitrogen use by Maize. In field experiments with Maize the aim was to find treatments giving the least loss of nitrogen by leaching or ammonia volatilisation. Maize has a slow early growth phase, its grand period of growth can be 3 or 4 weeks after the planting of the crop, depending on the weather. On loamy sand soils this can give rise to considerable losses of nitrogen by leaching.

The treatments compared included :-

Mineral Fertilisers
Slurry
Mineral fertilisers with nitrification inhibitors 'ALZON'
Slurry with Dicyanamide (DCD) nitrification inhibitors.

One of the first conclusions was that slurry gave significantly lower yields compared with equivalent amounts of fertiliser nitrogen. The reasons for this included loss of nitrogen as ammonia and the possibility of some nitrogen immobilisation. Applications of slurry to the growing crop were made using a tractor mounted tank with wide aperture long trailing tubes. The official extension service recommends that on land receiving regular slurry applications that all the ammonium N and 25 per cent of the total N is available in the season of application. This takes no account of ammonia loss.

Other workers at Hohenheim, Braschkat and Mannheimer were trying to quantify the emission of ammonia from slurries, they had developed some useful measuring devices but could show no conclusive results.

NUTRIENT UPTAKE

We visited several scientists who were conducting basic research on the uptake of nutrients. Though not particularly relevant at first sight it may help to understand the mechanisms of nutrient uptake in the field.

Mr Kusters (Hanover) is developing a model to increase our understanding of nitrogen uptake by lettuce. N uptake is modelled on a weekly basis in order to design a nitrogen recommendation system to minimise N use for maximum yield and minimum pollution. There were 8 Nitrogen treatments tested including a control, calcium nitrate and calcium ammonium nitrate sources. The rates of application were decided according to previous runs of the model for lettuce or the KNS system. The model appeared to simulate the production of fresh weight and nitrogen uptake fairly well . There was much discussion on the appropriateness of various factors such as density, light intensity and temperature on the growth of crops. It was felt that temperature was of primary importance to growth except at the later stages nearer maturity where the intensity of radiation is more important. They had found that later planted lettuce had higher yields and higher percentage dry matters than earlier planted crops. These differences may be related to radiation and Dr Scaife mentioned his effective day degree equations which allowed for the effect of radiation to be scaled by temperature.

Mr Schackt (Hanover) described a model designed to measure nutrient uptake in NFT cucumbers and showed how closely N uptake matched the variation in radiation. The efficiency of nitrogen uptake varied with Growth Stage, older plants taking up nutrients less efficiently than young plants. He showed that N uptake almost stopped at night. Feeding according to need, ie controlled by radiation and to temperature, gave similar yields and used similar quantities of nutrients to normal ad lib feeding.

Mr Steingrobe (Hanover) is investigating the transport of nutrients to plants and the critical concentrations necessary to achieve maximum rates of N uptake. His aim was to model nitrate uptake so that nitrogen supply could be adjusted to crop needs. This project is a growth cabinet study and may be extended to field soils later. We discussed factors likely to regulate nutrient uptake such as internal concentration of nitrate and ammonium.

At Gottingen, we met Professor Jungk the head of a team working on the techniques of modelling nutrient uptake, especially phosphate. They are studying rate of soil phosphate depletion, the rate of supply to plants roots, the uptake of the plants, and phosphate concentration of root exudates. We also discussed the differences between plants with and without root hairs. Plants have the ability to take up phosphate at even very low soil concentrations by the use of root hairs, mycorrhiza and other as yet unknown mechanisms.

Later we met Professor Tanner in Regensburg where we discussed the translocation of nitrogen into plants. Tanners's work suggested that nitrogen could be taken up by plant tissue independently of transpiration rate. If this is the case then the concentration of nitrogen in the xylem sap would be expected to vary proportionally, but this was not found in practice. One of his difficulties is the removal of large enough samples of xylem sap without affecting the system being measured.

In Neustadt we were told of an experimental programme investigating tipburn in lettuce. The experiments included examination of factors affecting tipburn. They intend to plant 25 crops of butterhead lettuce, one crop a week, and monitor the climatic conditions for each of the crops to see what factors are affecting the development of tipburn. If tipburn occurs they will also monitor the nutrient status of the soil. One of the factors they believe may be particularly important is irrigation. Too much early irrigation may give rise to plants with fewer roots thereby accentuating stress and tipburn later in the season. They have found module crops to be more susceptible to tipburn than drilled crops. They felt that this was related to the larger root development under drilled crop.

PROTECTED CROPS

Several of the horticultural institutes that we visited had research programmes for protected crops. At Hanover, Professor Scharf showed us some experimental areas of hydroponic and aeroponically grown chrysanthemums. Dr Ernst in Hohenheim showed me some work on tomatoes. Rockwool grown tomatoes were not popular and so as an alternative they were being grown in small trays of soil (of about the same volume as Rockwool blocks). We also saw some work being carried out by Dr Molitor at Geisenheim investigating the growth of chrysanthemums in 3 media:-

1) Recycling NFT. To reduce disease problems the crop was grown in short runs across rather than along benches. The water was biologically treated between cycles by passing it through a slow speed sand filter.

2) A Polyethylene layer system

3) Aeroponics

NITROGEN WORK AND ADVICE IN BELGIUM

We visited Dr G Hofman and Dr P Demyttenaere at the Department of Agricultural Soil Science, University of Ghent. The use of sap tests for potato and sugar beet crops were found to be unreliable. The Department was also involved in experiments testing banded applications of fertiliser to potatoes and sugar beet crops. They find that banded application reduces nitrogen requirement by as much as 20%. The banded fertiliser was applied using a Horstein spreader to make sure that none of the fertiliser is within 5cm of the seed.

Another programme of work includs regular and detailed monitoring of soil mineral N (once a month). The work showed very large variations in mineral N content between and within crop rows. It was also found that with potato crops the largest concentration of mineral N at harvest is actually in the top of the ridge because of little root activity in this dry zone. One student had done his entire PhD on the distribution of nitrogen across fields, this described the number of cores necessary to achieve certain limits of reliability in the final measurements of mineral N. These results have important implications on sampling methods adopted for measurement of soil mineral N, especially after harvest row crops such as cauliflowers.

The Department is also working on losses of nitrogen from different nitrogen sources in laboratory and field experiments. The experiment used 4 different soils and 4 fertiliser types.

Chalk soil	pH 8.2
Clay soil	pH 8.0
Loamy soil	pH 6.2
Heavy sandy loam	pH 6.8

Fertilisers being tested

- Ammonium sulphate
- Ammonium nitrate
- Urea
- 50% Urea, 50% ammonium nitrate

In the field experiments they were using masts or tunnels to measure the amount of ammonification from the sources of nitrogen. In the laboratory they were looking at factors such as temperature, calcium carbonate content, moisture content, depth of placement and dose rate on the loss of ammonium. Losses measured were in the order ammonium sulphate> urea> ammonium nitrate. Early experimental findings suggest that wetter soils lose less ammonia, and that placement of fertiliser is important. If for example, ammonium sulphate is applied on the surface, up to 30% of nitrogen can be lost, if it is placed 2cm below the surface then only 2% is lost, if placed 4cm down less than 0.06% is lost. They also compared the effect of dose rates, here there was no real difference between 100kg/ha and 200kg/ha in total amount lost. There were higher losses of ammonia from solid nitrogen than liquid applied nitrogen.

We spent some time discussing the use of soil mineral nitrogen measurements in predicting fertiliser requirements for vegetables like those used in the Netherlands, which were based on the German KNS system. We ascertained there were misgivings about some of the data in the system. Some Dutch workers believe they have more appropriate N uptake curves than those used in the KNS system. We also discussed the problem of using mineral N at harvest as a factor in predicting how much is necessary for maximum growth and agreed the approach may lead to over estimating N requirement. We also discussed the timing of mineral nitrogen measurements and decided that they were best done in mid-season rather than at planting. This timing requires a very rapid turn round of samples. In Belgium sampling for mineral N is done by the Government and results are available in 24/48 hours.

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